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Relative Catch Efficiency of Eight Collectors Using Two Aerially Applied Formulations of *Bacillus thuringiensis*

By

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Foreword

This report is published as a part of the USDA Forest Service program to improve aerial application of insecticides, specifically to apply insecticides more effectively and efficiently to eastern hardwood forests. The program is supported through the efforts of the Northeast Forest Aerial Application Technology Group (NEFAAT). This Group is composed of members from the United States Department of Agriculture Forest Service, Northeastern Area Forest Pest Management, and Northeastern Forest Experiment Station, Research Work Unit 4502; Animal and Plant Health Inspection Service (APHIS)-Gypsy Moth Methods Development Laboratory and-Aircraft Operations; and the Department of Entomology, Pennsylvania State University. Through cooperative efforts, the Group conducts field and laboratory studies to solve common problems associated with the application of biological insecticides in eastern hardwood forests. The Group also provides technical assistance in conducting training sessions to improve the quality of operational programs involving the aerial application of biological insecticides.

The NEFAAT Group has conducted six studies at the APHIS-Aircraft Operations Facility in Mission, Texas, from February 1985 through January 1989. Information provided in this Technical Publication is based on field activities conducted between February 12 and 17, 1985, and represents the fifth in a series of six publications.

Funding for this publication was provided by the Appalachian Integrated Pest Management (AIPM) Gypsy Moth Project.

Pesticide Precautionary Statement

This publication reports studies involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

Caution: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Introduction

The aerial application of insecticides to deciduous forests is the most widely used management strategy for suppression of gypsy moth in the northeastern United States. In the last decade, agencies have been directing more effort into reducing applications of traditional chemical insecticides and increasing the use of biological insecticides. Commercial formulations of the bacterium Bacillus thuringiensis Berliner var. kurstaki (Bt) are currently recommended for use in gypsy moth suppression projects.

In general, applications of Bt will provide foliage protection, although population reduction has not been consistently achieved (Harper 1974; Dubois, Reardon and Kolodny-Hirsh 1988). Applications of Bt are made using aircraft flown approximately 15 m (50 ft) above the canopy and often over complex terrain. In an effort to improve on-target foliage deposit of Bt, data should be collected on the fate of the spray following application. Current indications are that only near 50 percent of the released spray is deposited on the target (Barry et al 1978, Maksymiuk and Orchard 1973, and Bryant and Yendol 1988). In order to monitor the fate of sprays, a number of artificial collectors are available which catch spray and allow deposit quantification. However, the relative efficiencies and conditions for optimum use of these collectors varies. Relative efficiency depends mainly upon droplet size, wind speed, and collector size and orientation.

In an effort to utilize the results of previous investigations, and to determine the optimum collector for use under conditions associated with the aerial application of insecticides to deciduous forests, a comparison was needed of various collectors.

The objective of this study was to compare the relative collection efficiency, expressed as dose and numbers of droplets per unit area and droplet size, of 8 collectors. Two aerially applied formulations of Bt, one oil based and one aqueous based, were used in this study.

Material and Methods

Location. Experimental runs were conducted at the USDA-Animal and Plant Health Inspection Service (APHIS) Aircraft Operations facility (Moore Airbase, Edinburg, TX). This site provided a large area of flat terrain and few obstacles that might produce undesirable wind disturbances. Applications were made between February 12 and 17, 1985.

Formulations. Two commercial Bt formulations were selected. Both formulations have been commonly used in gypsy moth suppression programs, each having different physical properties at the same concentration of Bt per gallon of final spray mixture. All applications were at a rate of 7.01/ha (96 fl oz/ac) and dose of 30.0 Billion International Units (BIU) per ha (12 BIU/ac). The two formulations were as follows:

a. Thuricide 48LV (Sandoz Crop Protection, Chicago, IL), an aqueous flowable formulation containing 12.68 BIU/(48 BIU/gal) which was diluted 1 part Thuricide to 2 parts water, and

b. Dipel 8L (Abbott Laboratories, Chicago, IL), an oil based (EC) formulation containing 16.91 BIU/(64 BIU/gal) which was diluted 1 part Dipel to 3 parts water.

Red Powder 40 (Warner-Jenkinson Co., St. Louis, MO) was added to each formulation at a concentration of 1.20 g/ (16 oz/100 gal) of final spray mix. This tracer allowed deposit quantification using image analysis.

Aircraft and Atomization. Applications were made with Cessna Agtruck C188 (supplied by APHIS) which was fitted with 8 Micronair AU5000 rotary atomizers. Blade angle was set at 55° for all outboard atomizers, and 60° for the atomizers next to the fuselage. The variable restrictor unit (VRU) was set at 9 and the material applied at a pressure of 40 psi.

All applications were planned to be made into wind. However, because the collector line direction was fixed, many runs were made with some degree of crosswind. The Agtruck was calibrated for a 22.9 m (75 ft) lane separation, speed of the aircraft was 117 kmh (110 mph) and flew at a normal altitude of 15.3 m (50 ft) above ground level (agl). The spray was turned on and off approximately 500m (1500 ft) before and after the collector line.

Meteorological Data. Temperature was recorded during applications at 0, 0.95 m (3 ft) and 10.67 m (35 ft) agl. Wind speed and direction were recorded at 0.95m (3 ft) agl.

Collectors. A total of eight collectors were tested. All utilized a white Kromekote card as the collecting surface and are described as follows:

1) Horizontal Cards (CH), 16.51cm x 10.80cm (6.5in x 4.25in)(Randall 1980, Cadogan et al 1986, Maksymiuk et al 1973, Isler 1963).

2) Vertical Cards (CV), 16.51cm x 10.80cm (6.5in x 4.25in).

3) Coarse Aerosol Flag Samplers (EK) consisting of a collecting strip 3.81cm x 0.32cm (1.5in x 0.125in) mounted on a wire which always oriented it into the wind via a wind-vane and the wire inserted into a .95cm (0.04 in) diameter wooden dowel (Designed by Ekblad, Missoula Technological Development Center, Missoula, MO).

4) Small Vertical Cylinders (SC), 1.27cm x 16.51cm (0.5in diam. x 6.5in).

5) Large Vertical Cylinders (LC), 6.35cm x 16.51cm (2.5in diam. x 6.5in) (Barry et al 1982).

6) Horizontally oriented card shaped as a white oak (Quercus alba) leaf (LH), 53 cm^2 (3.23in^2).

7) Vertically oriented card shaped as a white oak leaf (LV), 53 cm^2 (3.23in^2).

8) Petri Dish (PH), 100 x 15mm (3.94in x .59in) containing a 98.5 mm (3.9 in) diameter card disk within the 15 mm (0.6 in) deep bottom dish.

Collectors were placed on wire stakes at 0.95 m (3 ft) agl and at ground level so as to compare collector efficiency as related to the two levels. The Petri dish samplers were placed only at ground level. The collection surface of each device was removed and replaced with a new one following each spray run. Four runs were conducted for each formulation of Bt.

Two deposit sample areas, each 6.1 cm^2 (0.95in^2), per card were measured using a Quantimet 900 image analyzer which had been calibrated to 35 um per pixel. Droplet size statistics were calculated using an Automatic Spot Counter and Sizing (ASCAS) computer program (Coburn 1964). Spread factors were determined by Yates (University of California, Davis).

Statistical Design and Analysis. A field plot 134 m (400 ft) wide was established and at 3.3 m (10 ft) intervals along the 134 m (400 ft) plot, a perpendicular column of 8 collectors was established. Each collector was separated by 3.3 m (10 ft). The order of placement of the collectors along each strip was determined by Latin square randomization. The experimental design utilized was a combination of 40 strips and five Latin square randomization of 8 x 8 blocks (figures 1a and 1b). Each column of 8 different collectors, oriented parallel with the aircraft flight line, was an experimental unit and resulted in a total of 40 units. Not all columns of collectors were used for each spray run analysis, because the swath widths and consequently the number of collector colums exposed to the spray varied from run to run. Columns were numbered from 0 to 390 by tens, to represent distance in feet.

The objective of the analysis was to determine if consistent differences resulted among collectors in terms of the number of droplets per cm^2, the dose per area (oz/ac) and droplet size (vmd). Differences were assessed as follows: 1) Were there consistent differences in deposit (quantity and form of deposit) caught by a collector due to collector design/position and was this deposit difference affected by the prevailing weather conditions? 2) How do different collectors portray the shape and size of an aircraft spray pattern? 3) Does the height of the collector influence the deposit collected?

From these assessments, a collector design/position will be recommended which meets the criteria for field use of accurate representation of spray present under a broad range of environmental conditions, combined with ease of use and deposit measurement.

A high degree of variability was expected between individual runs; therefore, a nonparmetric rank order procedure was used (Friedman's test) which uses the rank of the deposit received by a collector relative to other collectors in the same column. Collectors in the same column were assumed to be exposed to the same amount of spray. This test had the following advantages over analysis of variance of the raw data values: 1) The information contained in the rank order of collectors within a column with respect to each of the response measures was independent of the amount of spray actually applied to the column of collectors. As this amount was largely dependent on variable field conditions, it appeared that the rank order of response within a column of collectors represented the replicatable information from the study. 2) Using Friedman's test, it was possible to determine whether the rank order of collectors was consistent from collector column to column within a run. A Bonferroni procedure was used to identify groups of collectors which were significantly distinct at a pre-specified test-wide error rate (α=0.1), and 3) Zero responses from collectors with no deposit did not pose a problem to the rank order tests. Columns of collectors with more than 2 collectors containing zero deposit were excluded from the analysis.

In addition to the statistical analysis, graphs are presented for 4 of the 8 collectors showing the number of droplets per cm^2, the dose per area (oz/ac) and droplet size (vmd) collected by each collector across the width of the spray

pattern for 4 of the 8 runs. The 4 collectors chosen were 1) Horizontal card, 2) Vertical card, 3) Coarse Aerosol Flag Sampler and 4) Small cylinder. This combination of collectors was expected to show distinctly different collection characteristics under the various weather conditions of the runs because of their diverse designs.

The sum of the deposits for a given collector design, measured as oz/ac, was also used as an index of recovery.

Results

Eight spray runs were completed during the 4 days, under a variety of weather conditions (Table 1). Run 1 was made in a low wind speed which should favor collection by horizontal collectors. The other seven runs which were conducted with a significant amount of horizontal wind, tend to produce falling droplets with an inclined and more horizontal path, which would favor collection on vertical surfaces. Runs 1, 2, 5 and 7 were applied under stable conditions with an inversion present. Run 8 was applied under unstable conditions.

There was significant variability in the rank order of collectors from run to run, but not between runs of the two formulations of Bt. Therefore, comparisons of collector performance, using each response variable, are presented separately for each run and each sampling height (Tables 2a and 2b). Summary comparisons from all runs combined are shown in Table 3.

Table 1. Summary of weather conditions and flight direction for each spray run conducted at Mission, TX.

Run	Product	Date	Time a.m.	Wind Direction and Speed (MPH)	Flight Direction	Temperature 0'	3'	35'	% RH
1	Thuricide	2/12/85	7:05	NE, (10-20°) <1	310°	32	34	44	--
2	Thuricide	2/13/85	7:10	NE, (10-20°) 4	310°	41	42	47	100
3	Thuricide	2/13/85	10:30	NE, (140-145°) 18-20	130°	72	66	--	65
4	Dipel	2/14/85	7:00	NW, (335°) 6	310°	54	45	47	54
5	Dipel	2/14/85	10:30	NW, (340-350°) 6	310°	78	74	76	68
6	Dipel	2/14/85	7:48	SW, (330-335°) 8	310°	44	46	--	34
7	Dipel	2/16/85	7:04	E-SE, (75-85°) 6	130°	44	46	48	40
8	Thuricide	2/16/85	8:15	E-SE, (145°) 8	130°	62	60	56	60

Table 2a. Rank of collector types located at ground level for spray runs conducted in Mission, TX - 1985. Collectors are ranked in order of deposit from greatest to least for each response variable. Matching upper and lower case superscripts indicate groups of collectors which are significantly different at the experiment-wide error of $\alpha = 0.1$. All rankings shown are highly significant ($p<0.0001$).

Droplets/cm^2

Runs

1	2	3	4	5	6	7	8
A_{CH}	BA_{SC}	A_{EK}	BA_{SC}	A_{EK}	BA_{EK}	B_{EK}	B_{EK}
A_{LH}	B_{LH}	A_{LC}	BA_{EK}	A_{SC}	BA_{LC}	B_{SC}	B_{SC}
A_{PH}	B_{CH}	A_{LV}	B_{LC}	A_{LV}	BA_{SC}	B_{CH}	Ba_{LV}
SC	EK	A_{SC}	B_{LV}	A_{CH}	B_{CV}	a_{LH}	a_{LC}
EK	LC	A_{CV}	a_{LH}	A_{LH}	a_{CH}	ba_{PH}	ba_{CV}
LC	PH	a_{CH}	ba_{PH}	A_{CV}	ba_{LH}	ba_{LC}	ba_{CH}
a_{LV}	a_{LV}	a_{LH}	ba_{CH}	a_{PH}	ba_{LV}	ba_{LV}	ba_{LH}
a_{CV}	ba_{CV}	a_{PH}	ba_{CV}	a_{LC}	ba_{PH}	ba_{CV}	ba_{PH}

greatest

V

least

Dose per area (Oz/ac)

Runs

1	2	3	4	5	6	7	8
DBA_{CH}	BA_{CH}	A_{EK}	BA_{LC}	A_{SC}	BA_{LC}	DBA_{EK}	A_{EK}
DB_{LH}	BA_{LH}	A_{CV}	BA_{SC}	A_{EK}	BA_{EK}	DBA_{LH}	A_{SC}
D_{PH}	B_{SC}	A_{SC}	B_{EK}	A_{CH}	B_{CV}	D_{CH}	Ba_{CV}
SC	EK	A_{LV}	B_{LH}	A_{LV}	SC	D_{SC}	Ba_{LV}
EK	PH	A_{LC}	Ea_{LV}	A_{LH}	a_{LH}	a_{PH}	a_{CH}
a_{LC}	a_{LV}	a_{CH}	Ea_{PH}	A_{CV}	a_{CH}	ba_{LC}	a_{LC}
ba_{CV}	a_{LC}	a_{LH}	dba_{CH}	a_{PH}	a_{LV}	ba_{LV}	ba_{LH}
dba_{LV}	ba_{CV}	a_{PH}	$edba_{CV}$	a_{LC}	ba_{PH}	dba_{CV}	ba_{PH}

Volume median diameter (VMD)

Runs

1	2	3	4	5	6	7	8
BA_{PH}	A_{LH}	A_{CH}	$EDBA_{LC}$	A_{CH}	A_{LV}	BA_{LH}	$EDBA_{PH}$
B_{CH}	CH	SC	EDB_{LH}	A_{LH}	LC	B_{PH}	CH
B_{LV}	PH	LV	EDa_{PH}	A_{CV}	PH	CH	LH
LH	LV	EK	Eba_{LV}	A_{SC}	LH	a_{CV}	ea_{CV}
SC	SC	a_{LH}	ba_{EK}	A_{EK}	CH	a_{LC}	eba_{SC}
CV	CV	a_{CV}	ba_{SC}	A_{LV}	CV	a_{EK}	eba_{EK}
a_{LC}	a_{LC}	a_{PH}	dba_{CH}	a_{PH}	a_{SC}	ba_{SC}	dba_{LV}
ba_{EK}	a_{EK}	a_{LC}	$edba_{CV}$	a_{LC}	a_{EK}	ba_{LV}	$edba_{LC}$

CH = Horizontal Cards
CV = Vertical Cards
EK = Course Aerosol Flag Sampler
SC = Small Vertical Cylinder
LC = Large Vertical Cylinder
LH = Horizontal White Oak Leaf
LV = Vertical White Oak Leaf
PH = Petri Dish

Table 2b. Rank of collector types located at 1m (3 ft) above ground for spray runs conducted at Mission, TX - 1985. Collectors are ranked in order of deposit from greatest to least for each response variable. Matching upper and lower case superscripts indicate groups of collectors which are significantly different at the experiment-wide error of $\alpha = 0.1$. All rankings shown are highly significant ($p<0.0001$).

Drops/cm^2

Runs

1	2	3	4	5	6	7	8
A_{EK}	DBA_{EK}	BA_{EK}	BA_{EK}	BA_{SC}	BA_{LC}	BA_{EK}	A_{EK}
A_{LV}	DB_{SC}	B_{LC}	B_{SC}	B_{EK}	B_{LV}	B_{SC}	A_{SC}
A_{LH}	D_{LC}	B_{LV}	B_{LC}	B_{LV}	B_{SC}	B_{LC}	A_{LV}
CH	Ea_{LV}	B_{SC}	Da_{LV}	Da_{LH}	Da_{EK}	Da_{LV}	A_{LC}
LC	ba_{LH}	Ba_{CV}	Dba_{LH}	Da_{CH}	Da_{CV}	ba_{CV}	a_{CV}
SC	dba_{CH}	ba_{CH}	dba_{CV}	Da_{CV}	dba_{CH}	ba_{CH}	a_{LH}
a_{CV}	$edba_{CV}$	ba_{LH}	dba_{CH}	dba_{LC}	dba_{LH}	dba_{LH}	a_{CH}

greatest
|
V
least

Dose per area (Oz/ac)

Runs

1	2	3	4	5	6	7	8
A_{CH}	DBA_{EK}	A_{EK}	BA_{LC}	BA_{SC}	DBA_{LC}	BA_{EK}	BA_{EK}
A_{LV}	DB_{SC}	A_{LV}	B_{EK}	B_{EK}	DB_{LV}	B_{SC}	BA_{SC}
A_{LH}	a_{LV}	A_{CV}	B_{SC}	B_{LV}	D_{CV}	Ba_{LC}	B_{LV}
LC	a_{CH}	A_{LC}	Da_{LV}	B_{LH}	a_{SC}	Ba_{LV}	Da_{LC}
EK	ba_{LC}	A_{SC}	ba_{LH}	Ba_{CH}	ba_{EK}	ba_{CH}	Da_{CV}
SC	ba_{LH}	a_{CH}	dba_{CV}	Ba_{CV}	dba_{LH}	ba_{LH}	dba_{CH}
a_{CV}	dba_{CV}	a_{LH}	dba_{CH}	ba_{LC}	dba_{CH}	ba_{CV}	dba_{LH}

Volume median diameter (VMD)

Runs

1	2	3	4	5	6	7	8
BA_{LH}	BA_{CH}	A_{LV}	A_{LC}	A_{CH}	BA_{LC}	A_{CH}	DBA_{CH}
BA_{CH}	B_{LH}	A_{CV}	Ba_{SC}	A_{LH}	BA_{LH}	A_{LH}	DB_{SC}
BA_{CV}	B_{SC}	A_{EK}	Ba_{LV}	A_{CV}	B_{LV}	LV	DB_{CV}
BA_{LV}	B_{CV}	A_{SC}	Ba_{LH}	A_{SC}	CV	LC	D_{EK}
B_{SC}	B_{LV}	LC	Ba_{EK}	A_{LV}	CH	EK	a_{LH}
a_{LC}	a_{EK}	a_{LH}	ba_{CH}	A_{EK}	a_{SC}	a_{CV}	ba_{LV}
ba_{EK}	ba_{LC}	a_{CH}	ba_{CV}	a_{LC}	ba_{EK}	a_{SC}	dba_{LC}

CH = Horizontal Card
CV = Vertical Card
EK = Course Aerosol Flag Sampler
SC = Small Vertical Cylinder
LC = Large Vertical Cylinder
LH = Horizontal White Oak Leaf
LV = Vertical White Oak Leaf
PH = Petri Dish

Table 3. Rank of collectors across combined spray runs - Mission, TX - 1985. A low p-value indicates a significant consistent rank ordering across runs (Friedman's test). Matching upper and lower case superscripts indicate groups of collectors which are significantly different at the experiment-wide error of $\alpha = 0.1$.

Drops/cm^2

Ground Level	3' Above Ground Level
^{A}EK	^{A}EK
^{A}SC	SC
CH	LV
LC	^{a}LC
LH	^{a}LH
LV	^{a}CV
^{a}PH	^{a}CH
^{a}CV	
p=0.007	p<0.0001

Dose per area (Oz/ac)

Ground Level	3' Above Ground Level
^{A}EK	EK
SC	LV
CH	SC
LH	LC
LC	CH
LV	CV
CV	LH
^{a}PH	
p=0.012	p=0.0047

Volume median diameter (VMD)

Ground Level	3' Above Ground Level
^{A}LH	CH
PH	LH
CH	LV
LV	CV
CV	SC
SC	LC
LC	EK
^{a}EK	
p=0.053	p=0.242

Droplet density (droplets/cm^2). In the majority of cases (6 out of 8 runs at 3 ft and 5 out of 8 runs at ground level) the EK collector caught the greatest number of droplets. This result is further shown in the figures for runs 1, 6, 7, and 8 where EK collected the highest deposit amounts, with the exception of run 1 (ground level - D), which had the low wind speed. The EK design, with its small catching area, had a high collection efficiency under the wind conditions found in these tests. This collector is especially beneficial for collecting finer aerosol sprays (<150um). The vertical cylinders (SC and LC) and vertical leaves (LV) also ranked high as collectors of droplets. The horizontal cards (CH), leaves (LH) and the Petri dish (PH) were consistently poor collectors of droplets at both sampling heights. The vertical cards (CV) also showed poor collection efficiency, even though their collection orientation was favorable for the wind speeds in these runs. The size of these collectors provided low collection efficiency for the droplet sizes available for capture.

Dose per area (oz/ac). The dose per area (oz/ac) determinations showed similar trends when compared to droplet density. In low wind speed of 4 mph or less, and under strongly stable condition as in run 1 and to a lesser extent run 2, the horizontal collectors (CH, LH, PH) ranked high on the basis of dose per area. The vertical cards (CV) and cylinders (SC and LC) ranked low for dose per area collected. This may be due to the steep trajectory, relative to collector orientation, of droplets falling under low windspeed conditions and the fact that small droplets will not easily penetrate the strong inversion. Overall, the EK and small cylinders (SC) ranked highest in terms of dose per area collected, but differences were not significant. This is apparent from the figures for runs 1, 6, 7, and 8 where the EK collector showed the greatest catch within a given run.

Drop size (volume median diameter). Droplet size (vmd) results showed that horizontal collectors, especially those with a large area, such as the horizontal cards (CH), collected the largest vmd. This does not suggest that large targets are good collectors of large droplets but that they are, instead, poor collectors of small droplets. The poor collection efficiency of spray volume represented by small droplets will produce a relatively high vmd measurement. The small vertical collectors, such as the EK and the small vertical cylinders (SC), were relatively efficient collectors of small droplets. Therefore, the deposit on these collectors includes droplets from the smaller droplet fraction. These rank differences, while consistent between spray materials and constructed from an average of all runs, do not show a significant difference in droplet size caught by the different collectors (Table 3). Similarly, the vmd averaged over runs for a given collector show only small differences in droplet size between collectors (Table 4).

Table 4. Average volume median diameter (vmd), expressed in μm, collected across all collectors of a given type, for a given run - Mission, TX - 1985.

Ground Level

Collector	Run							
	1	2	3	4	5	6	7	8
LH	163.3	200.2	133.4	139.2	77.9	121.3	100.3	161.0
PH	138.0	153.8	105.0	118.2	----	111.1	95.8	157.5
CH	178.8	187.4	130.5	127.0	100.9	108.9	98.1	164.2
LV	136.7	187.4	145.4	107.3	74.7	119.0	90.4	138.7
CV	150.7	174.2	159.9	126.8	80.6	108.6	87.3	150.5
SC	190.4	184.4	153.6	105.5	79.3	103.8	77.1	150.8
LC	187.0	185.4	129.1	142.5	87.8	110.4	86.0	126.7
EK	172.1	180.0	137.9	108.0	74.6	111.6	81.8	147.0

3' Above Ground Level

Collector	Run							
	1	2	3	4	5	6	7	8
CH	149.4	189.3	102.8	121.0	88.1	103.7	95.3	164.1
LH	154.0	179.9	113.2	108.3	80.4	113.9	97.7	146.9
LV	157.8	177.0	159.9	108.2	80.0	118.1	93.6	139.1
CV	175.0	181.2	155.6	124.7	74.4	110.1	89.8	154.6
SC	177.3	180.3	159.5	104.3	88.0	106.1	86.4	153.7
LC	177.9	164.2	140.4	138.7	36.5	114.1	90.1	128.8
EK	122.2	178.4	155.0	103.8	77.5	91.1	94.3	139.2

Spray Pattern Shape. The shape and location of the spray patterns were very similar for each collector. Because of the physical layout of the types of collectors, which meant that collectors at a given distance from the centerline could be separated by as much as 27 m (80 ft) in the direction of the flightline, some of the variation in deposit seen within a column of collectors was due to differences in amount of spray available for capture as well as any differences associated with collector type. In general, the small vertical collectors which have been shown to be more efficient collectors of small droplets, will portray a greater pattern width compared to large horizontal collectors. This effect is due to more efficient collection of the fine spray droplets which tend to occur at the edges of the swath pattern, and the downwind tail of patterns extended by crosswinds.

Collector Height. The sum of the deposit collected on all collectors of a given type was used as an index of collector performance within a given run (Table 5). In general, the horizontal collectors (card horizontal-CH and leaf horizontal-LH) had greater deposits across the swath when placed at ground level. In contrast, the vertical collectors (e.g. course aerosol flag-EK and small cylinder-SC) generally gave greatest deposits when at 3' agl. These phenomena are probably caused by the different airflows at the two collector heights; collectors at 3 ft will have airflows with both greater horizontal velocity and the potential for vertical motion. Since deposition on vertical collectors increases with increasing wind speeds, deposits on vertical collectors will be highest at 3 ft. The vertical wind speed associated with turbulence at 3 ft will make the collection efficiency decrease for the horizontal collectors. Droplet collection on horizontal collectors is due to sedimentation and vertical air velocity allows droplets to flow around the

collector instead of sedimenting to the target. Similarly, horizontal collectors at ground level will benefit from increased vertical sedimentation in the reduced wind speeds near the ground.

Table 5. Sum of deposit expressed as oz/ac, collected across all collectors of a given type, for a given run - Mission, TX - 1985.

Ground Level

Collector	Run 1	2	3	4	5	6	7	8
EK	125.5	467.6	925.3	460.5	560.6	497.8	204.2	5179.6
SC	153.5	428.9	353.7	464.9	104.5	142.3	96.0	3183.7
CH	339.3	424.0	46.3	74.8	48.8	72.7	128.8	1495.2
LH	263.3	442.5	33.1	361.1	----	76.4	141.2	1092.5
LC	88.4	226.2	235.2	693.0	36.3	204.9	74.1	1460.1
LV	68.7	211.3	280.2	232.5	0.1	69.6	73.6	1916.8
CV	76.6	190.2	372.6	45.5	32.6	126.1	68.0	1855.4
PH	253.1	386.6	26.7	208.3	76.3	47.4	107.5	1106.5

3' Above Ground Level

Collector	Run 1	2	3	4	5	6	7	8
EK	128.3	1259.7	1784.8	1108.9	462.4	182.9	485.9	8634.8
LV	159.2	557.8	688.6	519.4	83.8	381.2	228.1	4007.6
SC	105.7	885.9	765.1	848.4	186.6	258.6	255.0	6350.4
LC	134.0	415.7	680.4	1446.2	0.1	413.2	279.8	2469.7
CH	136.2	439.9	48.1	77.2	38.2	52.6	131.5	878.8
CV	78.5	319.8	720.8	83.7	29.7	244.5	130.2	3661.5
LH	155.4	396.1	36.6	217.8	61.7	112.9	139.3	545.7

Discussion

The collectors evaluated in these runs were selected as representative of those previously used to quantify spray deposit associated with the aerial application of insecticides to broadleaved trees (Reardon et al, in press). As expected, there was a high degree of variability in deposit among collectors between individual runs although collectors were consistent in columns within a run. Since the amount of deposit depends, in part, on wind speed, estimates of the wind speed in the immediate vicinity of the collectors are necessary to correct the amount caught due to collection efficiency for comparison of these droplet distribution data with previous data on a given collector.

The influence of collector size, orientation and surface characteristics on droplet collection has been known for a long time (Spillman 1984). These data generally support the hypothesis that highest collection efficiencies are obtained from small target collectors oriented vertically under all but the slowest wind speeds or largest spray droplet size. Under most conditions associated with the aerial application of insecticides to broadleaved trees, where the vmd of sprays is often below 200 um and the winds greater than 3 mph, then vertical collectors of high collection efficiency will provide the best collector, as shown by the EK and SC designs.

In general, the collector which catches the most spray will be the most accurate estimator of airborne spray concentration since a passive collector cannot collect more spray than was actually exposed to it. Thus, the larger the amount per area caught, the nearer will be the value to the theoretical true maximum value. Small sized collectors such as the EK and SC, drinking straws (Sanderson et al 1984), nylon spheres (Yendol, personal communication) or strings (Whitney and Roth 1985, Parkin et al 1985) therefore have an advantage over large horizontal cards or large cylinder collectors and are essential when collecting

fine sprays. However, the method of deposit measurement used should also be considered when selecting a collector. If tracer wash-off techniques are to be used, then the use of small collectors is possible, providing sufficient tracer can be collected from the collection device to provide a reliable measurement. If image analysis is used to quantify deposit, then the collection device will need to be large enough to read a sufficient area to provide an accurate estimate of the average deposit over the whole collector. The collector must also be flat to allow a uniform plane of focus for the imaging camera. This limits image analysis to either vertical or horizontal flat collectors, or cylindrical collectors which can be flattened after application, as used in these spray runs.

Traditionally, horizontal cards positioned on the ground or at 3' agl in an open area for calibration/characterization trials or positioned beneath tree canopies for operational spray trials have been used to simulate target deposition. Unfortunately, we have documented in several intensive field trials that neither the droplet deposit on the horizontal cards in the open nor beneath the canopy of broadleaved trees have any relationship to that deposited on the target foliage. Since it is not practical to use the target foliage as the collector, a combination of collectors (e.g. horizontal cards and small cylinders) should be used during characterization or operational trials to gather sufficient data concerning their relative collection efficiencies for a broad range of environmental conditions. In association with these trials, there is a need to relate deposit on these collectors to that actually deposited on the target foliage.

It is not possible based on these data to make recommendations as to the "best" collector for all environmental conditions nor to provide a relative collection efficiency for each collector. Even though the collection efficiencies for each collector are highly variable, there is an urgent need to develop a collector

for use during calibration/characterization trials and operational programs involving broadleaved trees. The standard horizontal cards placed on the ground or 3 feet agl do not provide a deposit profile which can be related to the deposit on the target foliage. Vertical collectors of high collection efficiency (e.g. small cylinders) under most conditions associated with the application of insecticides to broadleaved trees should be used along with other collectors in an effort to develop a deposit database for a broad range of environmental conditions.

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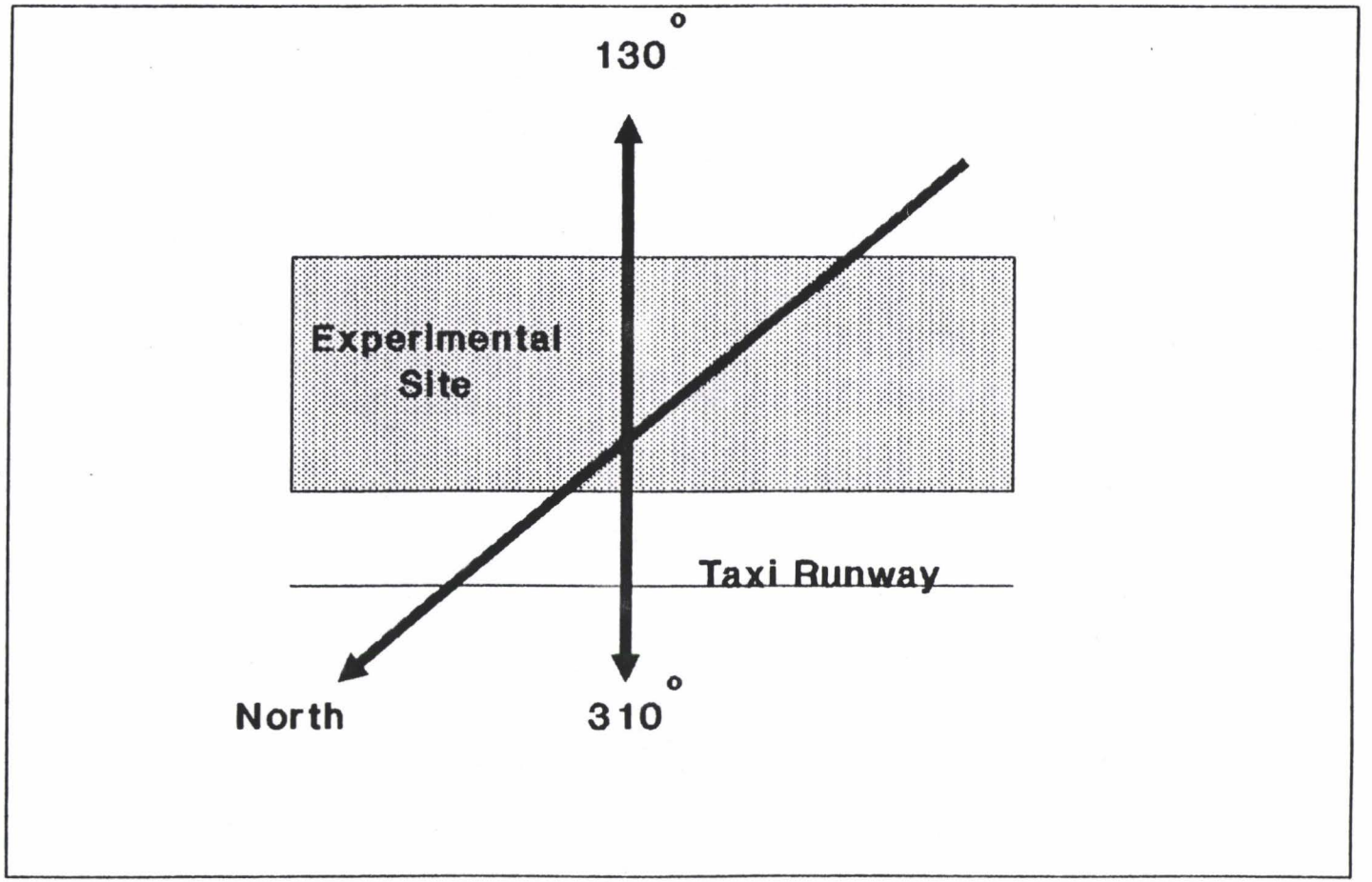
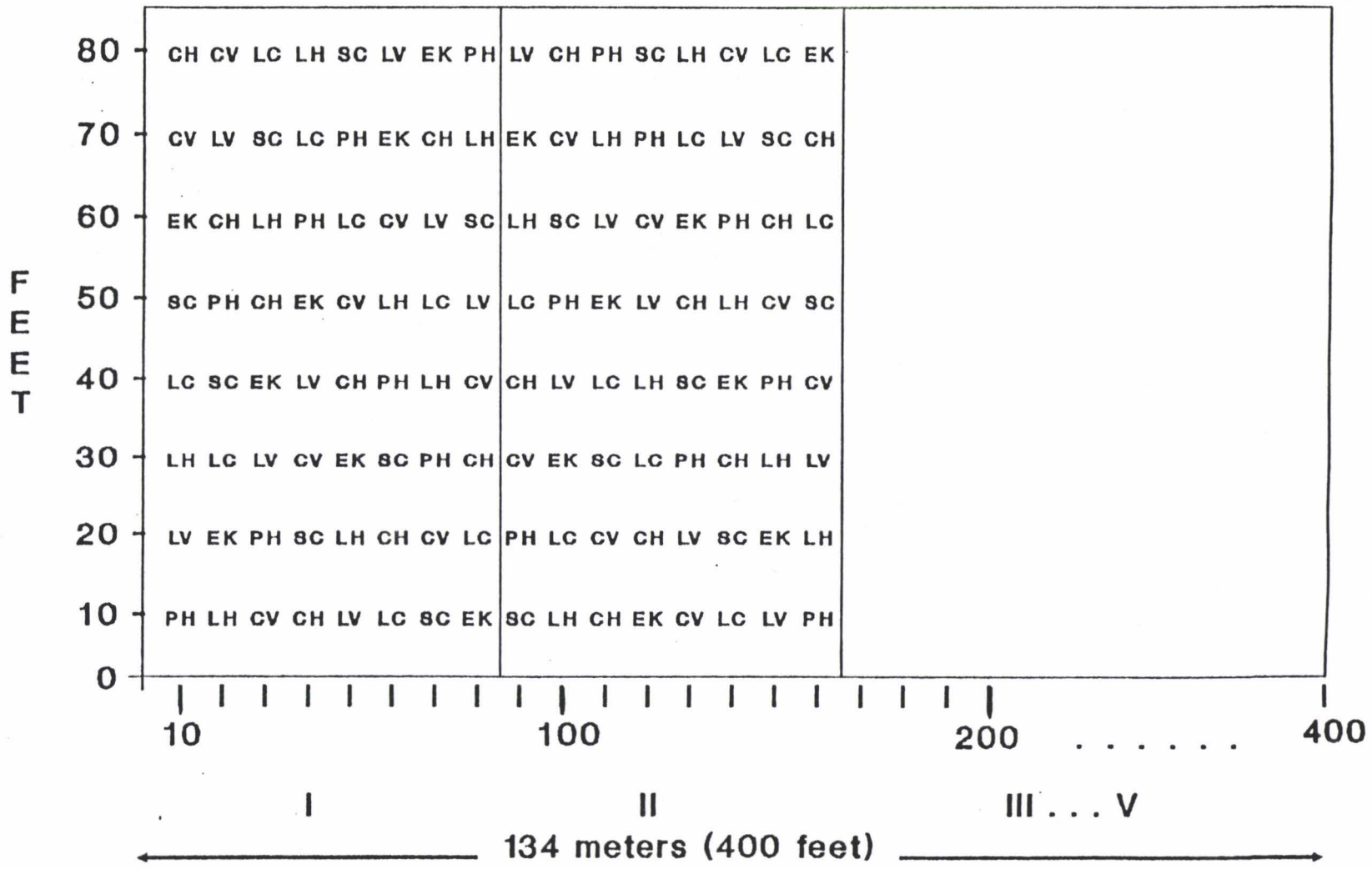


Figure 1a. Area diagram of the experimental site in relationship to taxi runway and direction of flight path.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70
60
50
40
30
20
10
0
FEET
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CV LV SC LC PH EK CH LH
EK CH LH PH LC CV LV SC
SC PH CH EK CV LH LC LV
LC SC EK LV CH PH LH CV
LH LC LV CV EK SC PH CH
LV EK PH SC LH CH CV LC
PH LH CV CH LV LC SC EK
LV CH PH SC LH CV LC EK
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LH SC LV CV EK PH CH LC
LC PH EK LV CH LH CV SC
CH LV LC LH SC EK PH CV
CV EK SC LC PH CH LH LV
PH LC CV CH LV SC EK LH
SC LH CH EK CV LC LV PH
10
100
200
400
I
II
III . . . V
134 meters (400 feet)

Figure 1b. Experimental design for evaluation of eight collectors, Mission, TX - 1985.

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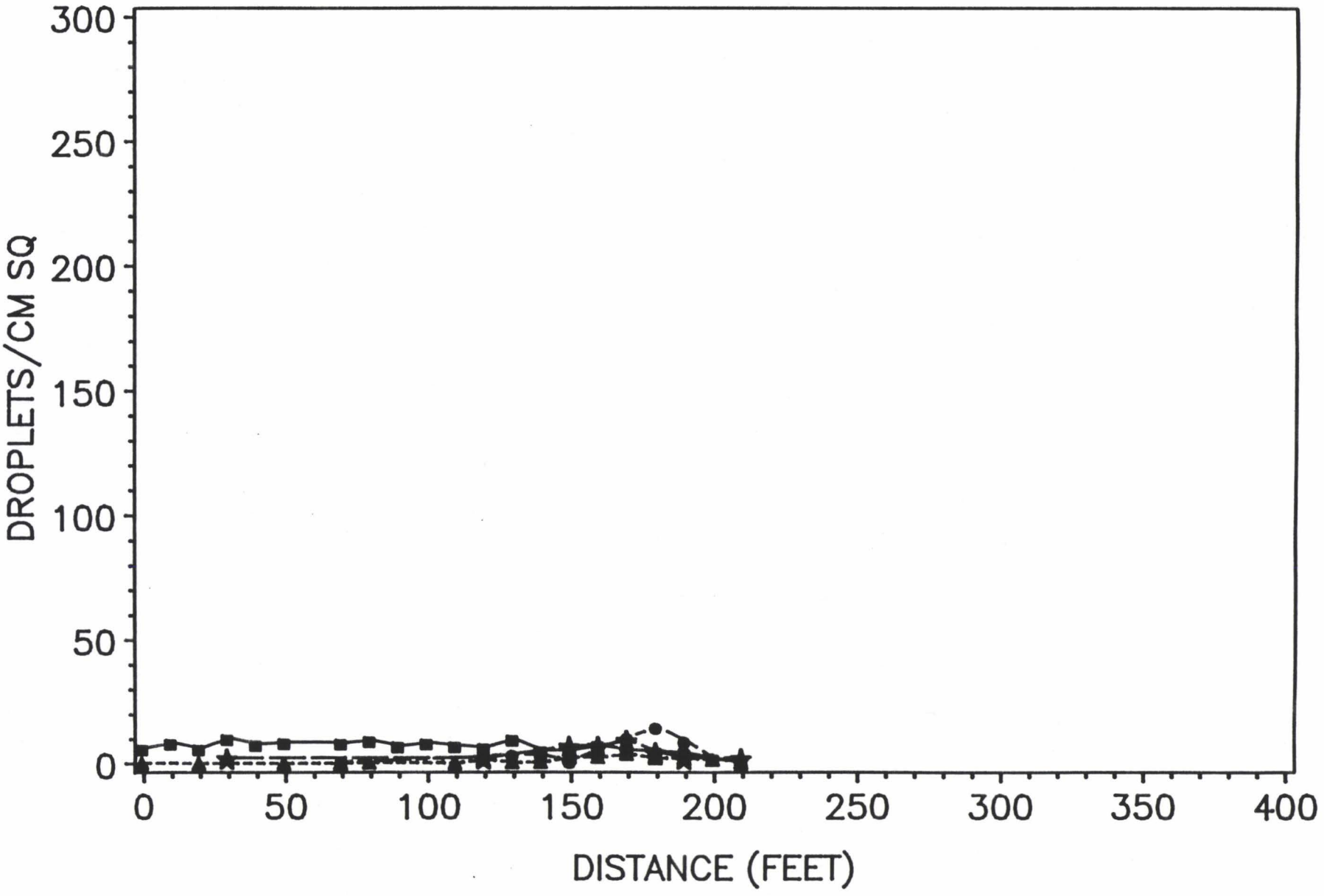

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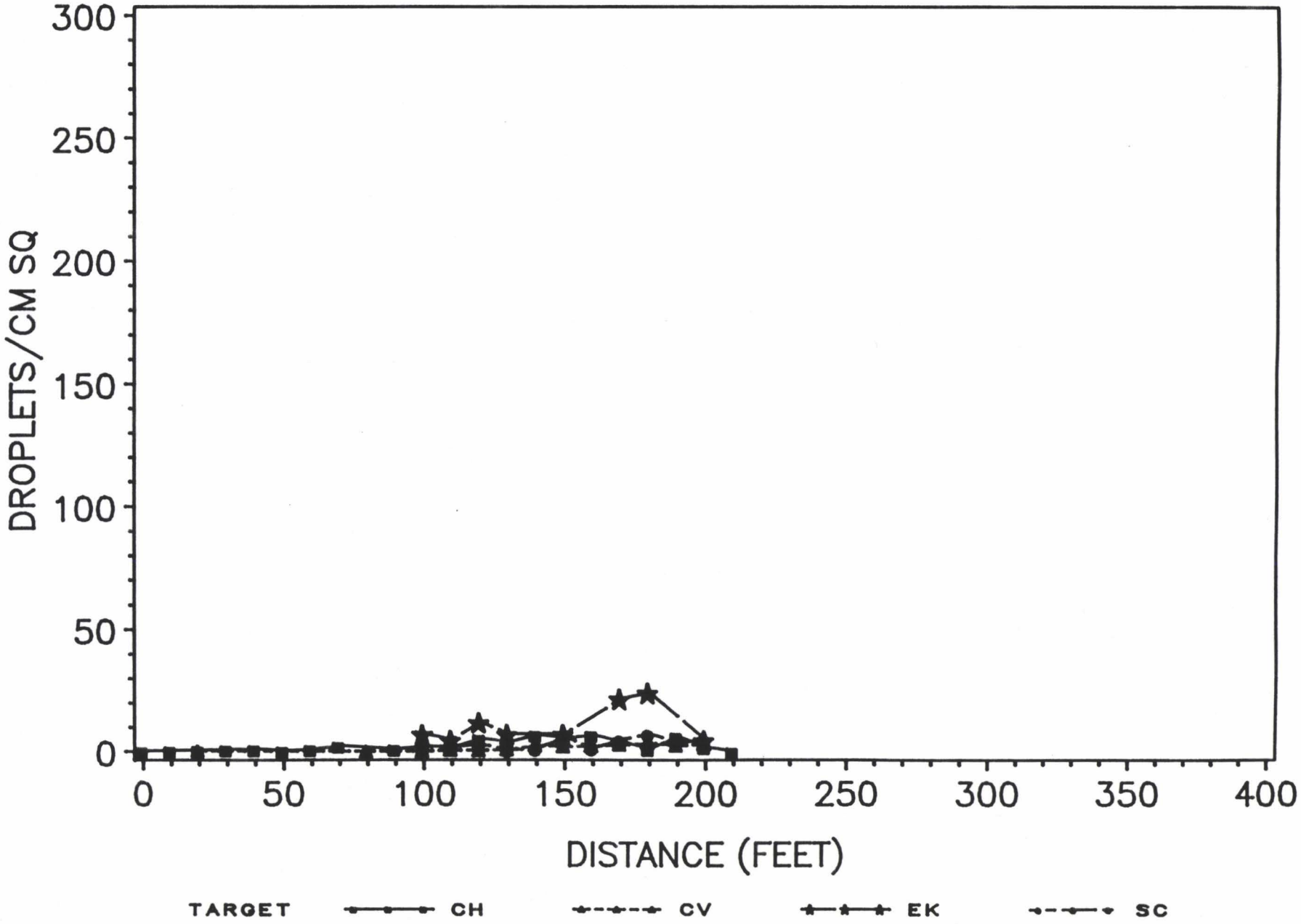

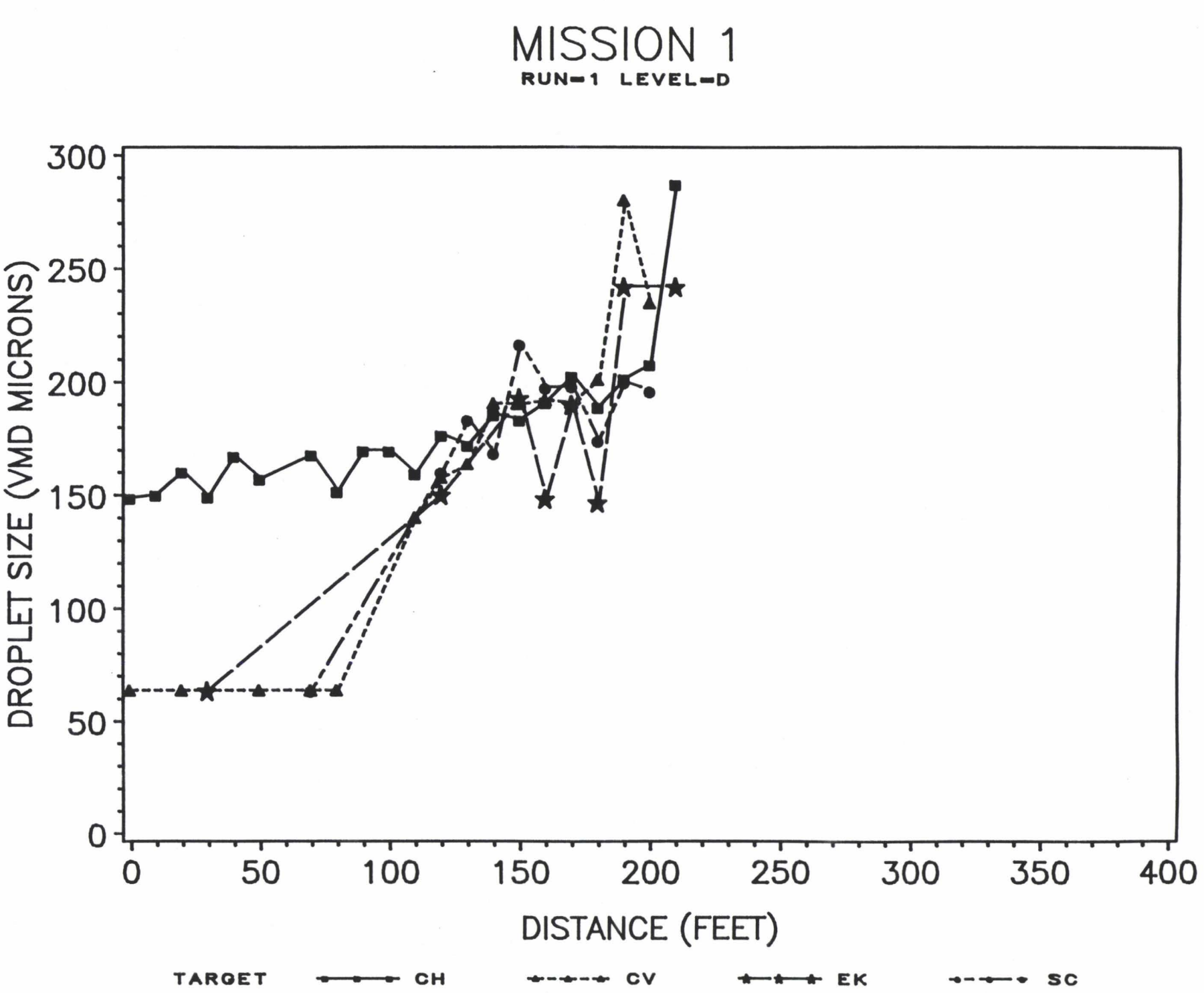
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50
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0
50
100
150
200
250
300
350
400
DISTANCE (FEET)
TARGET
CH
CV
EK
SC

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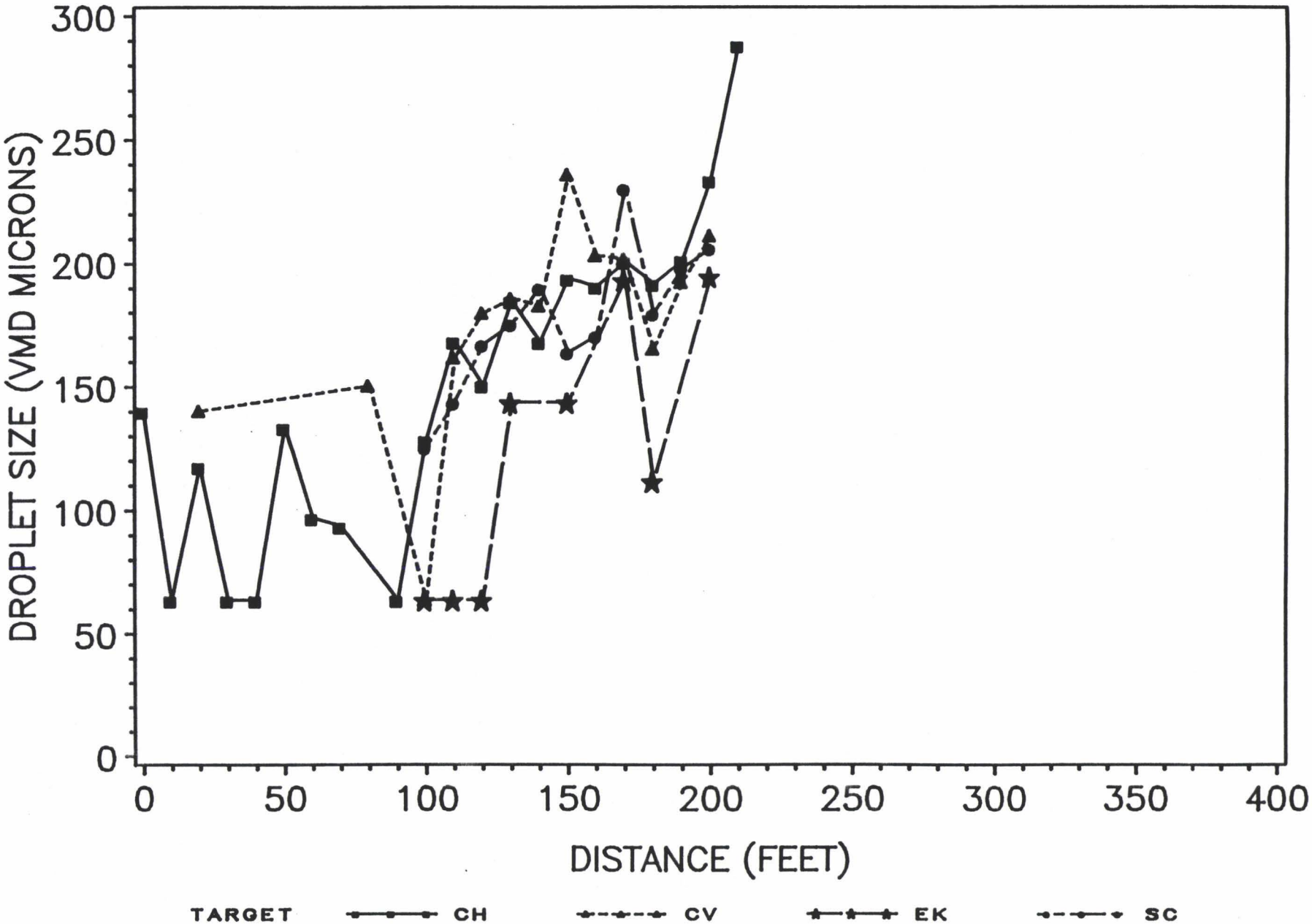

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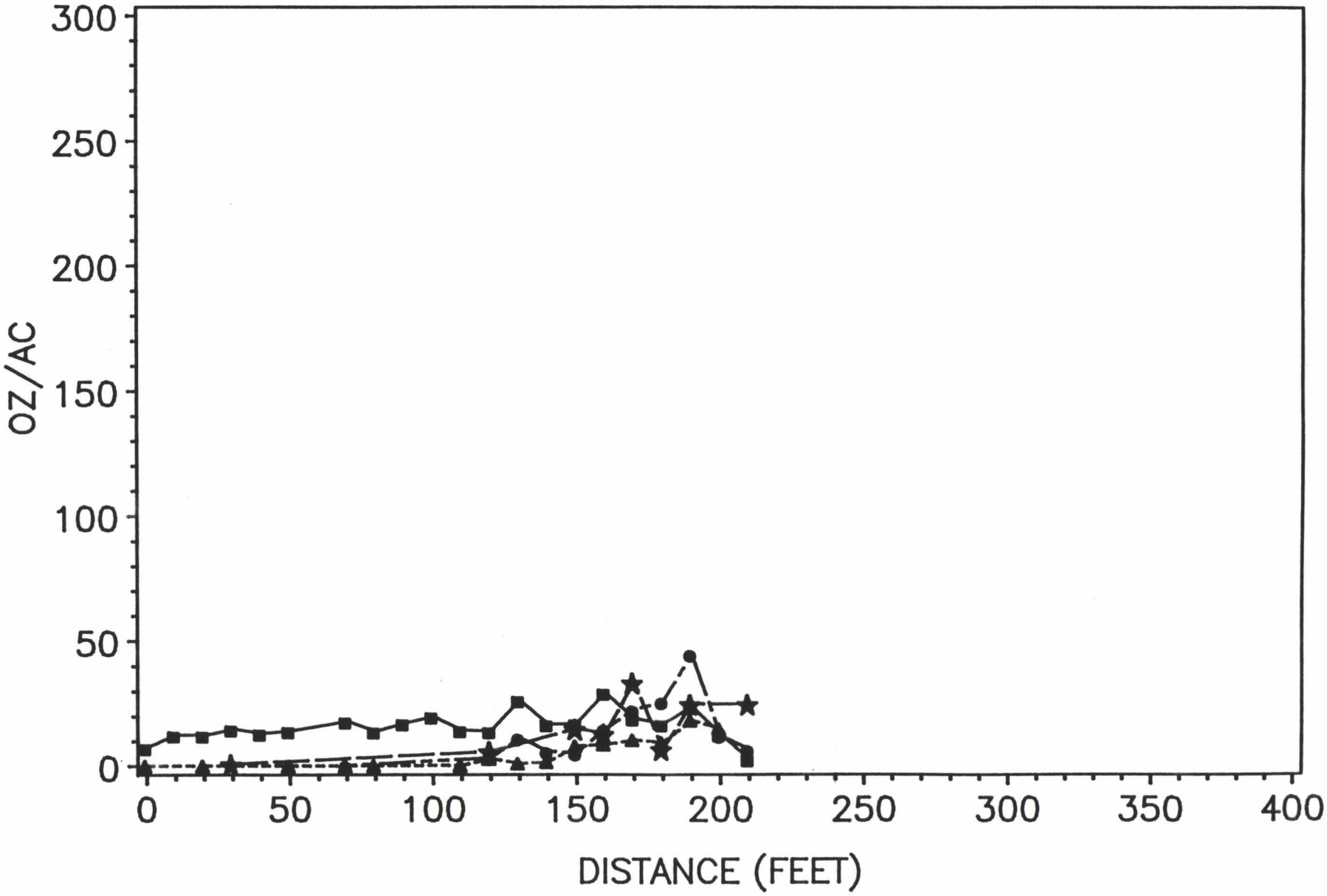

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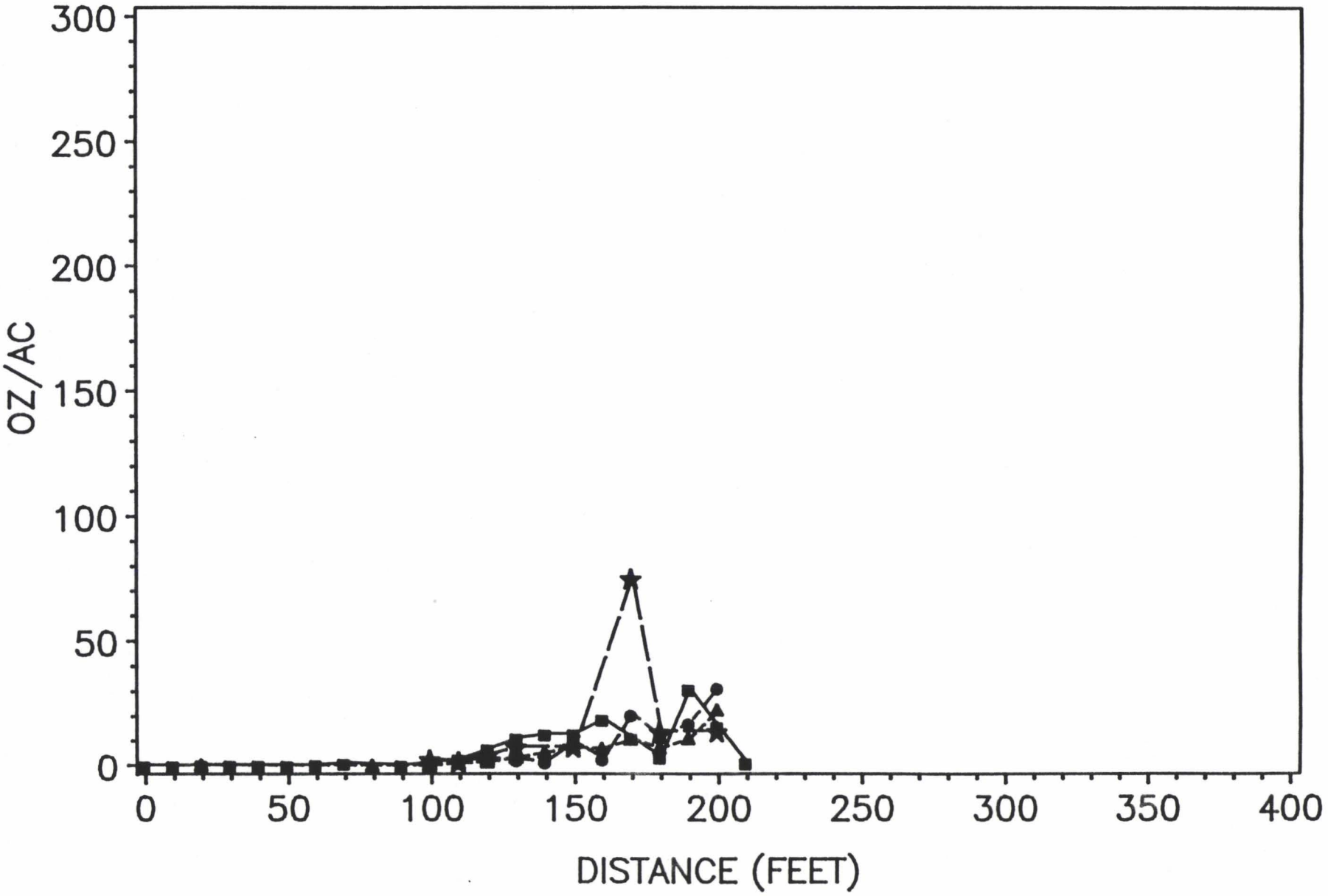

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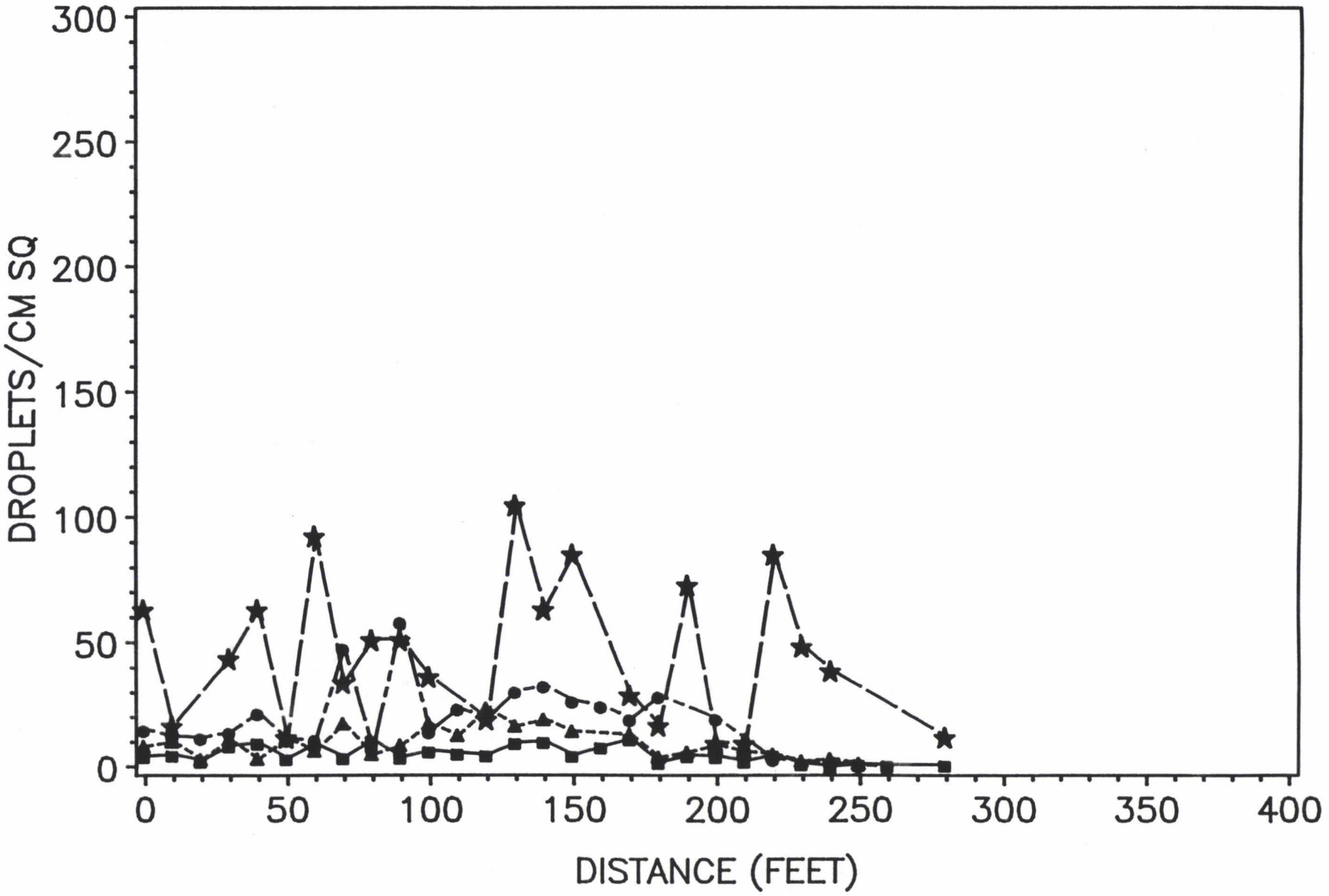

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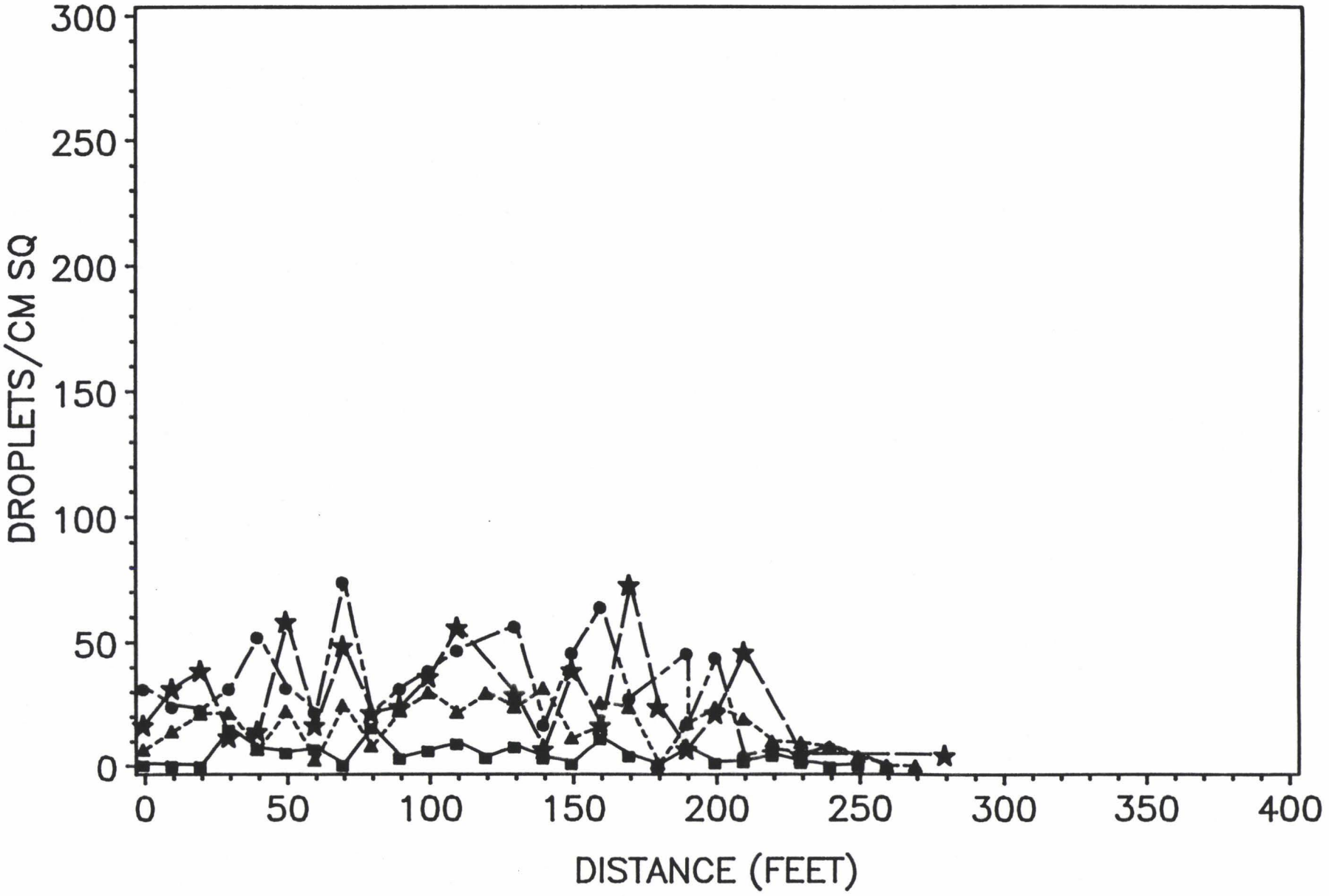

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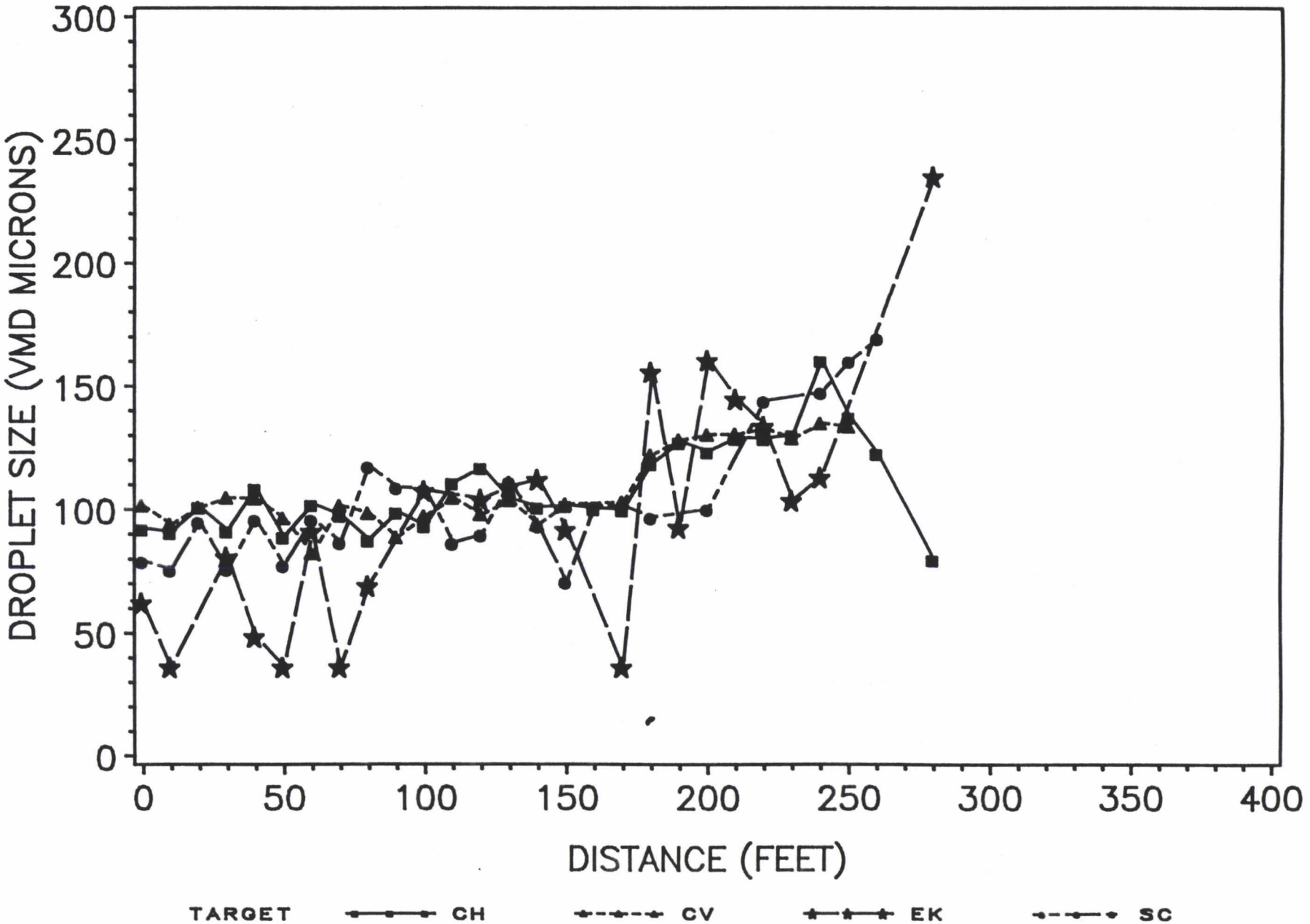

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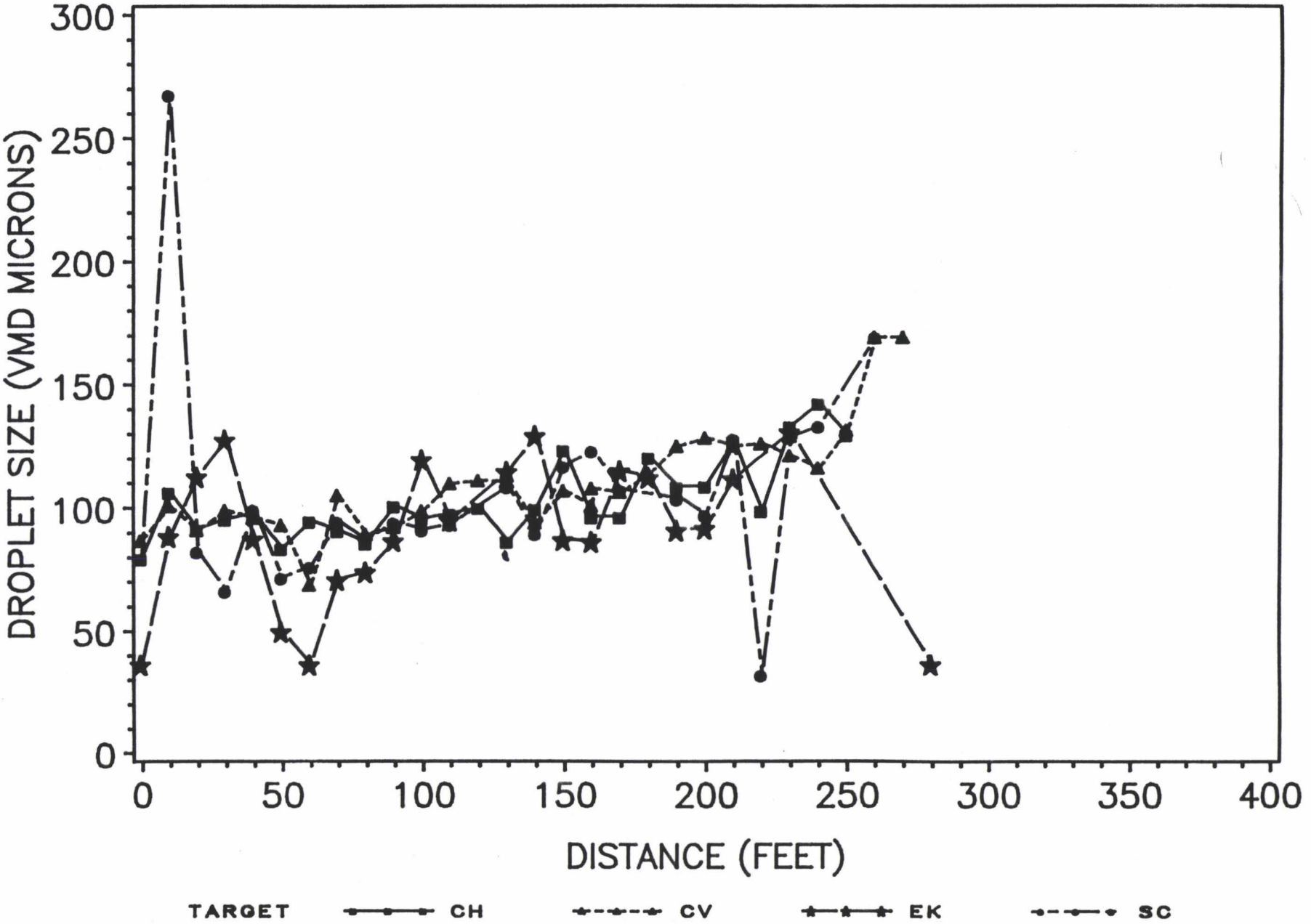

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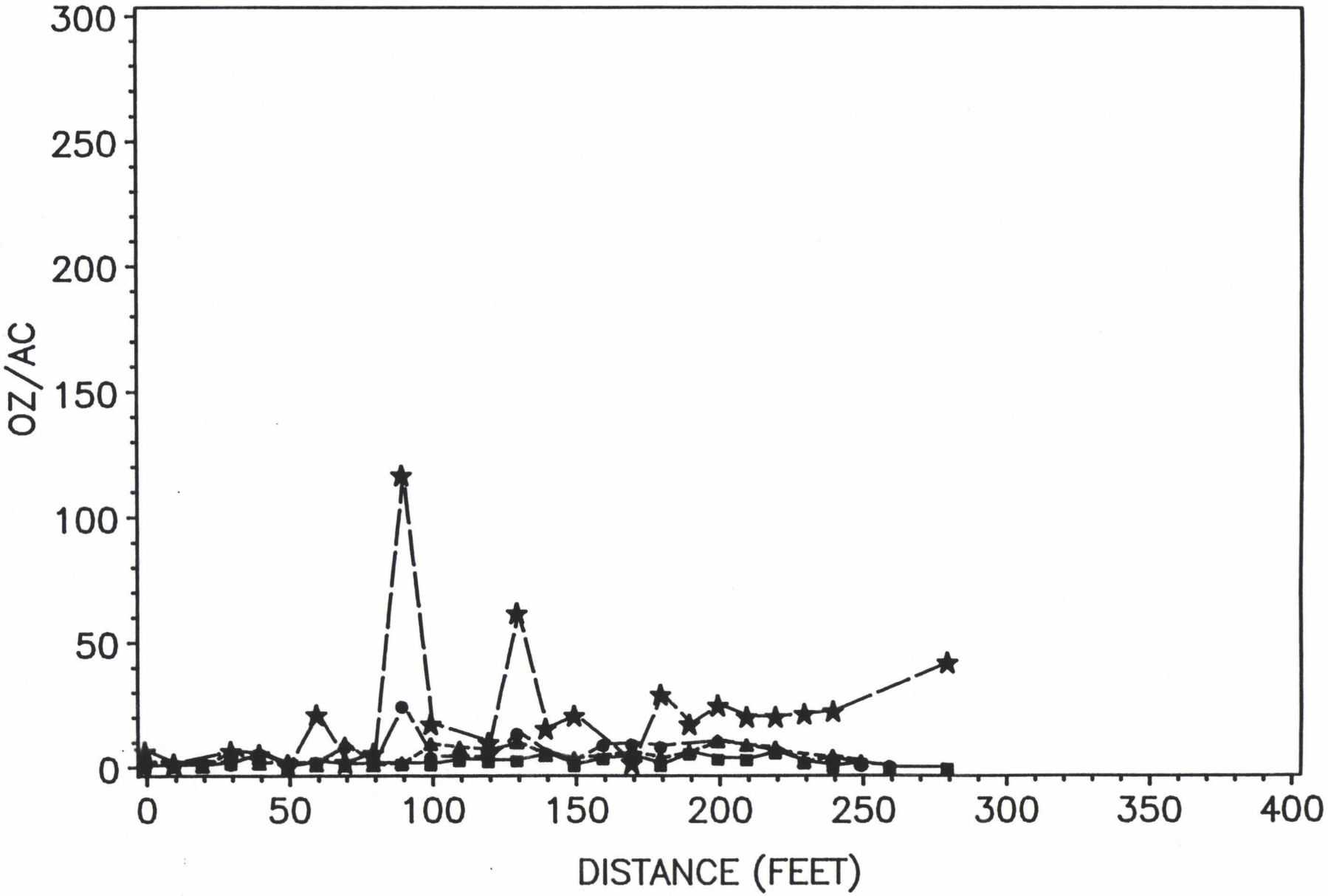

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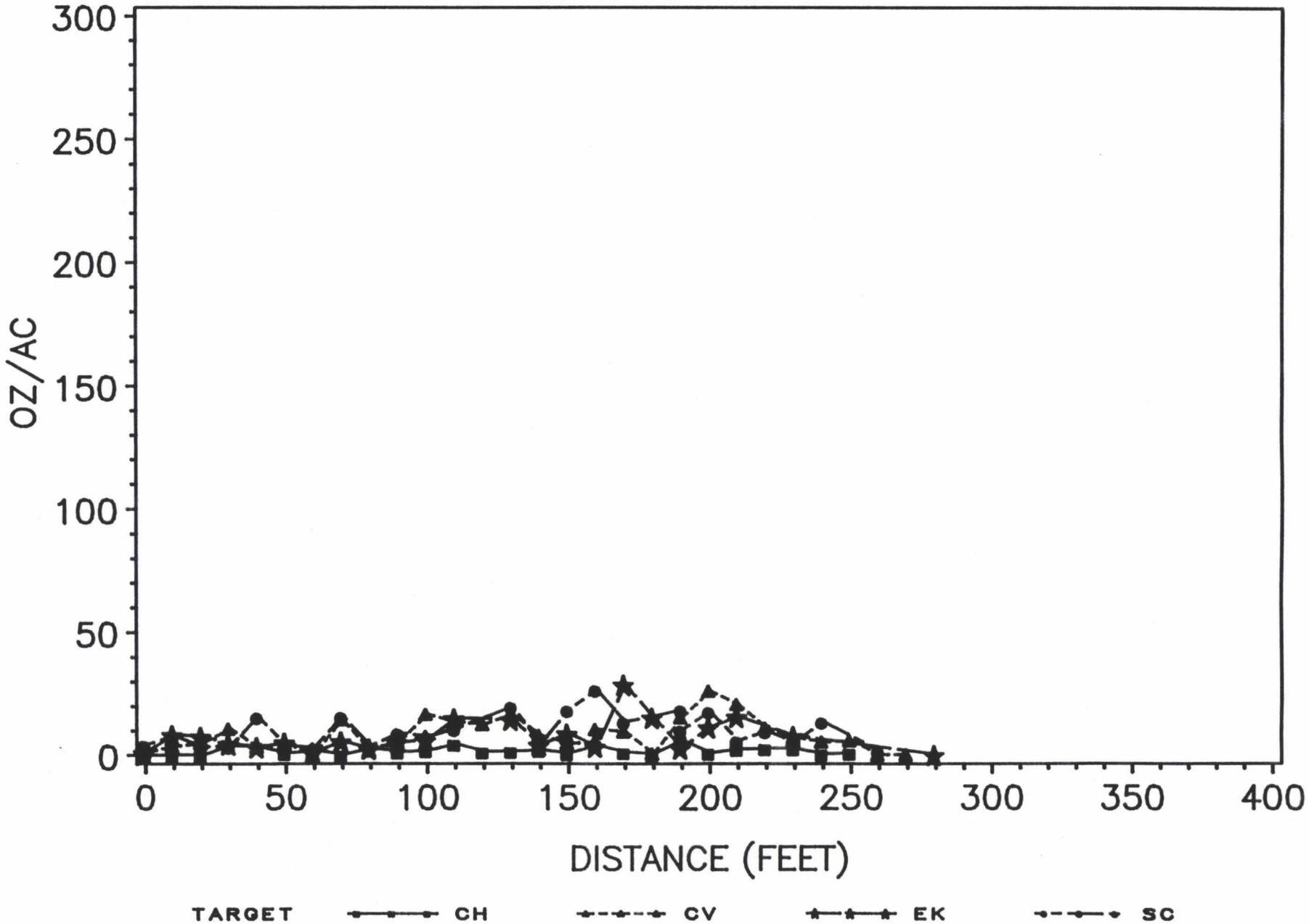

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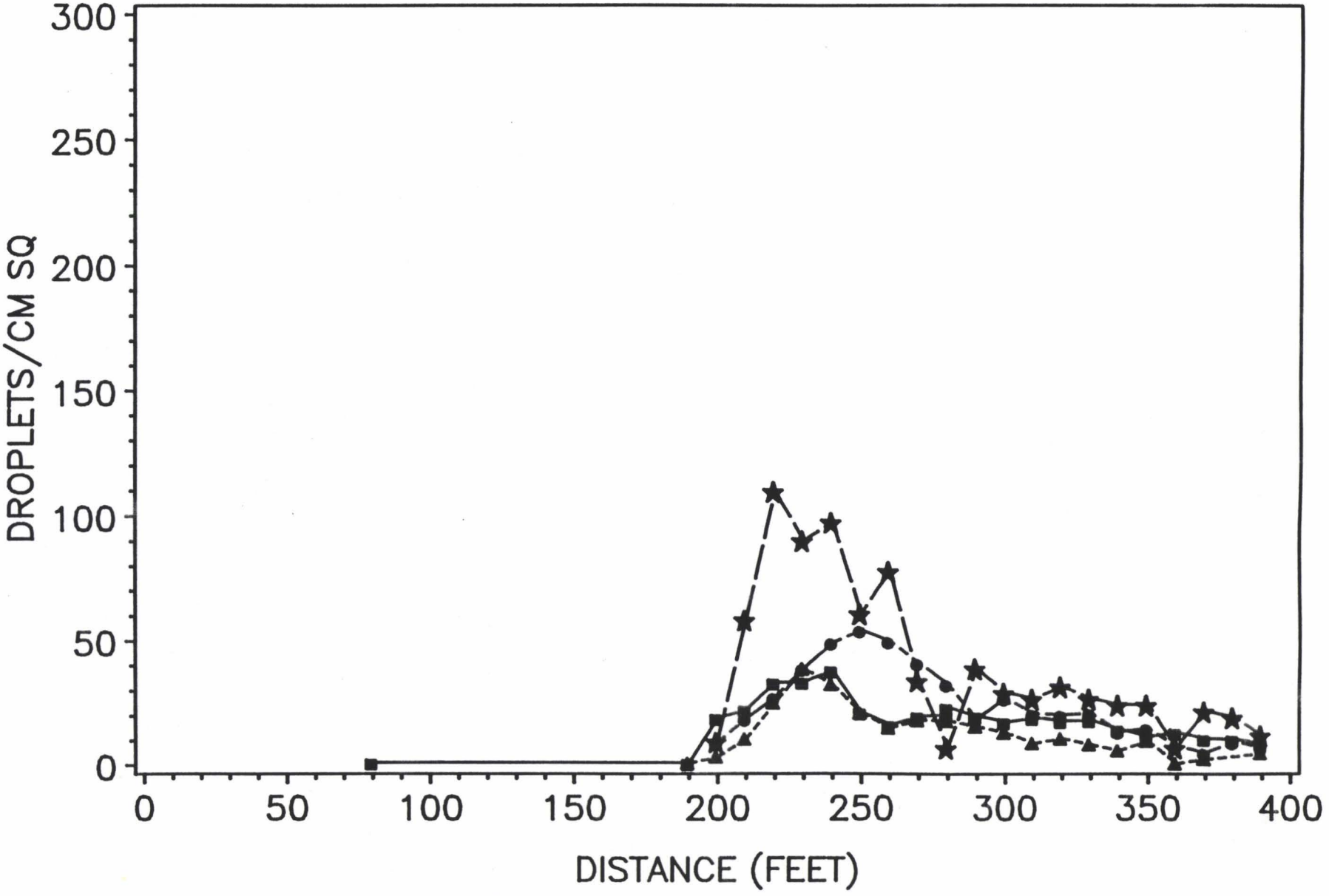

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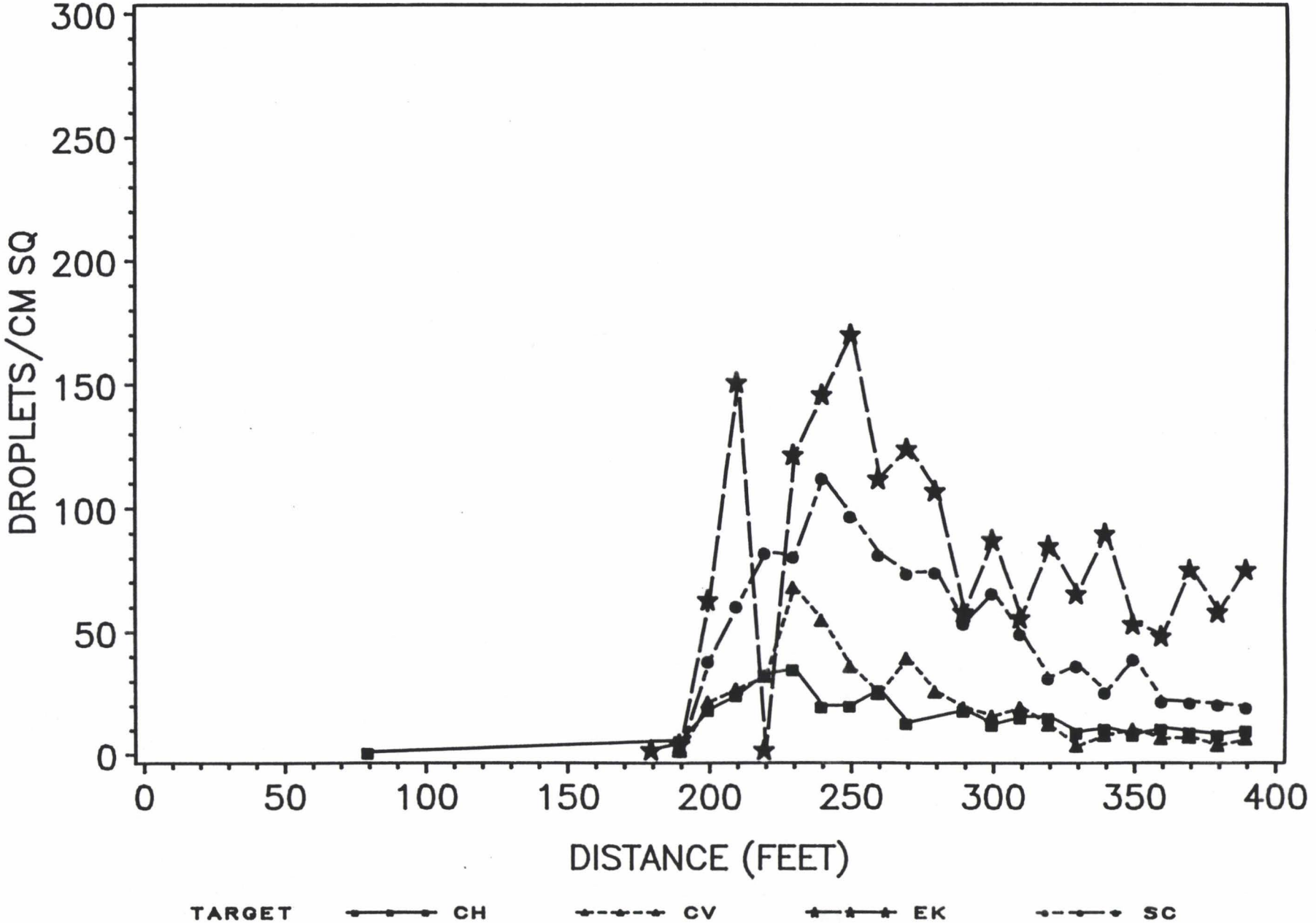

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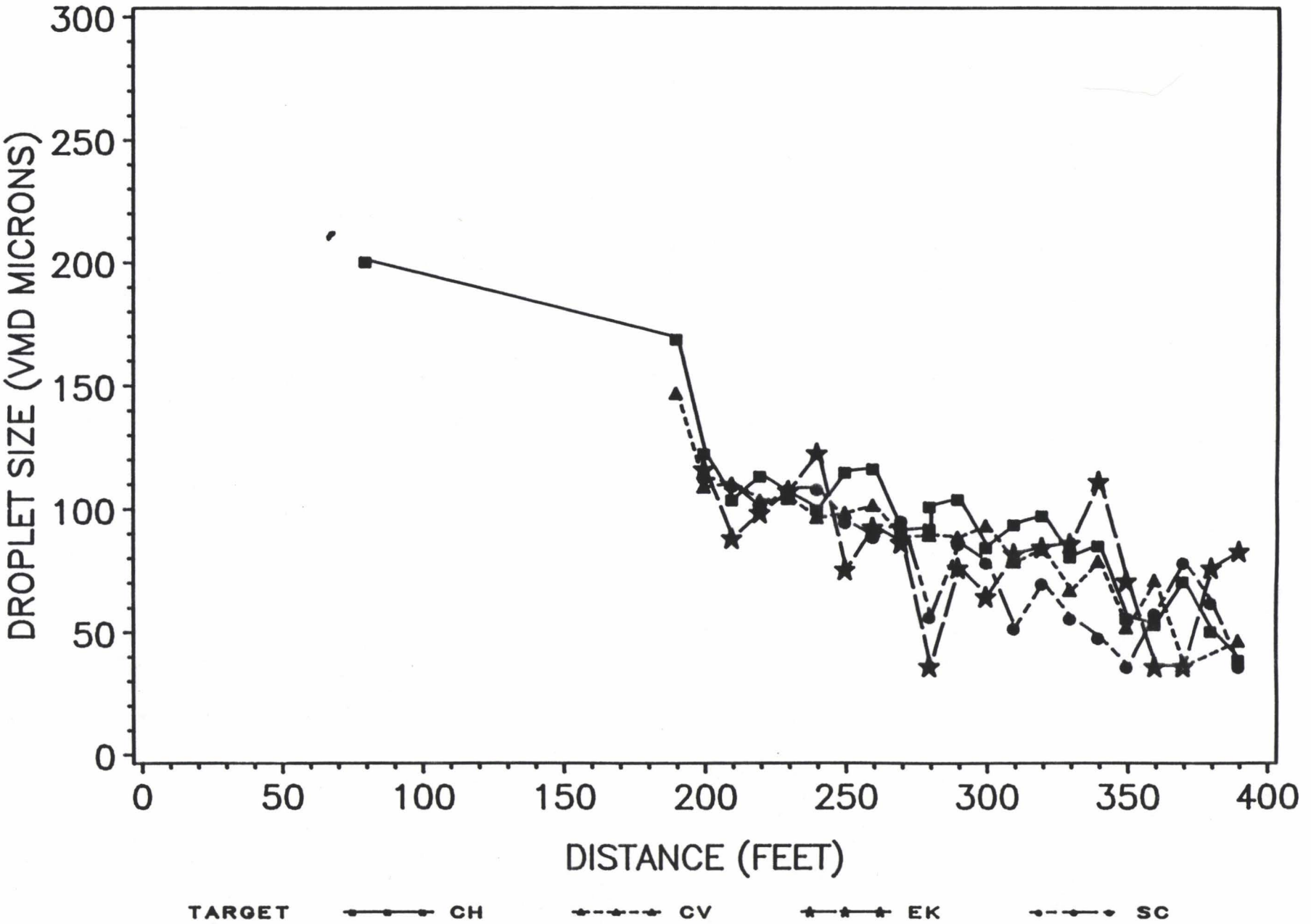

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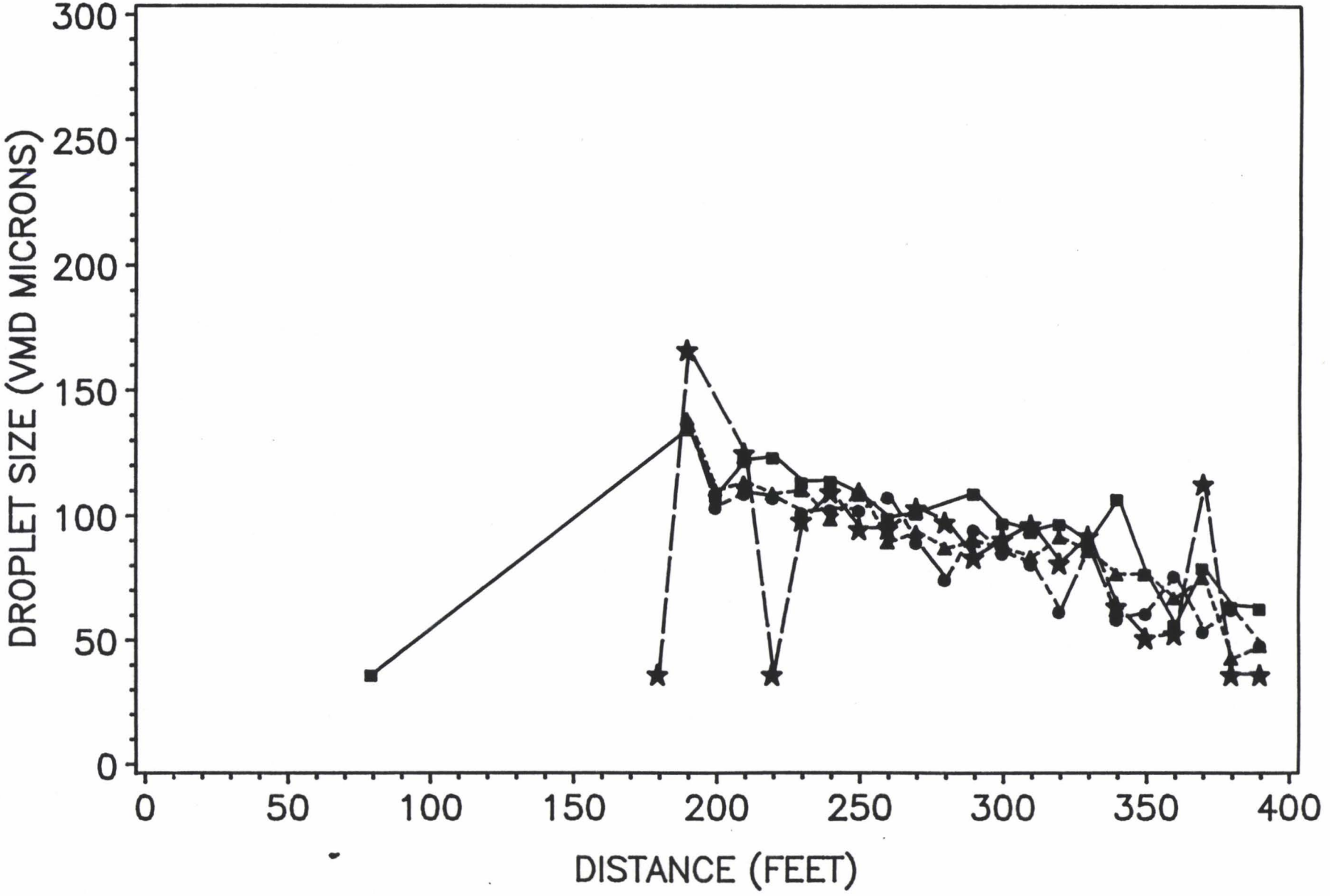

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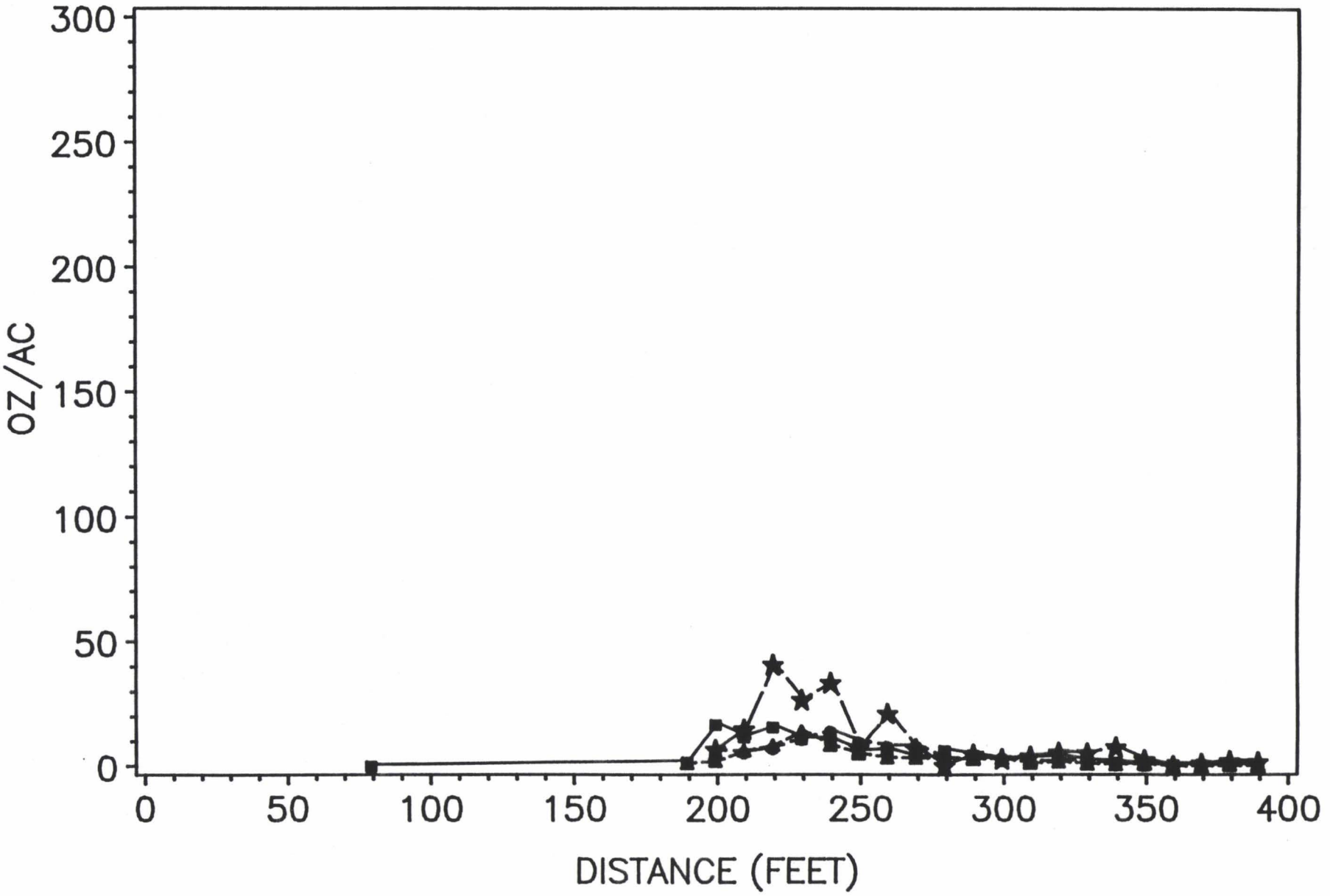

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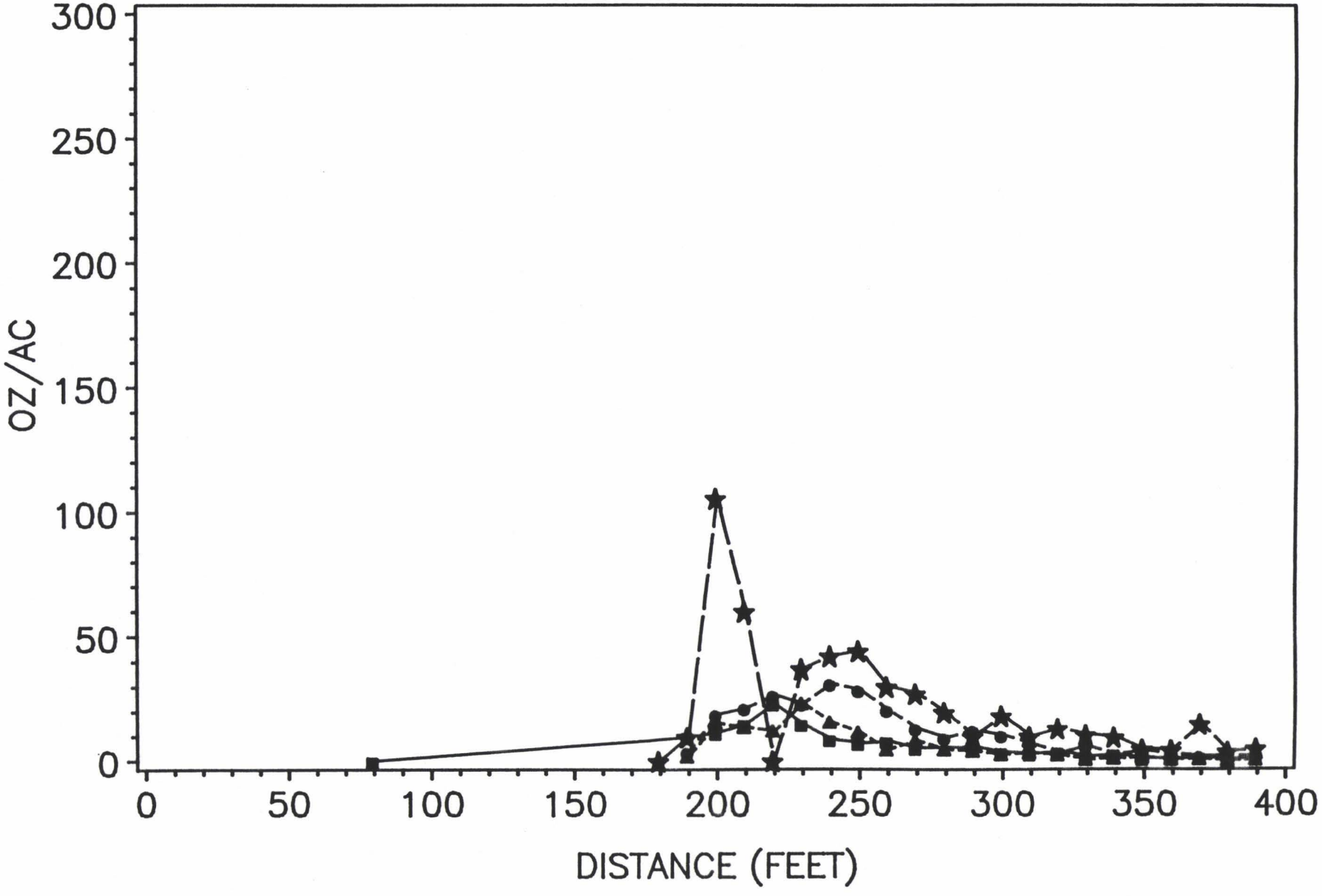

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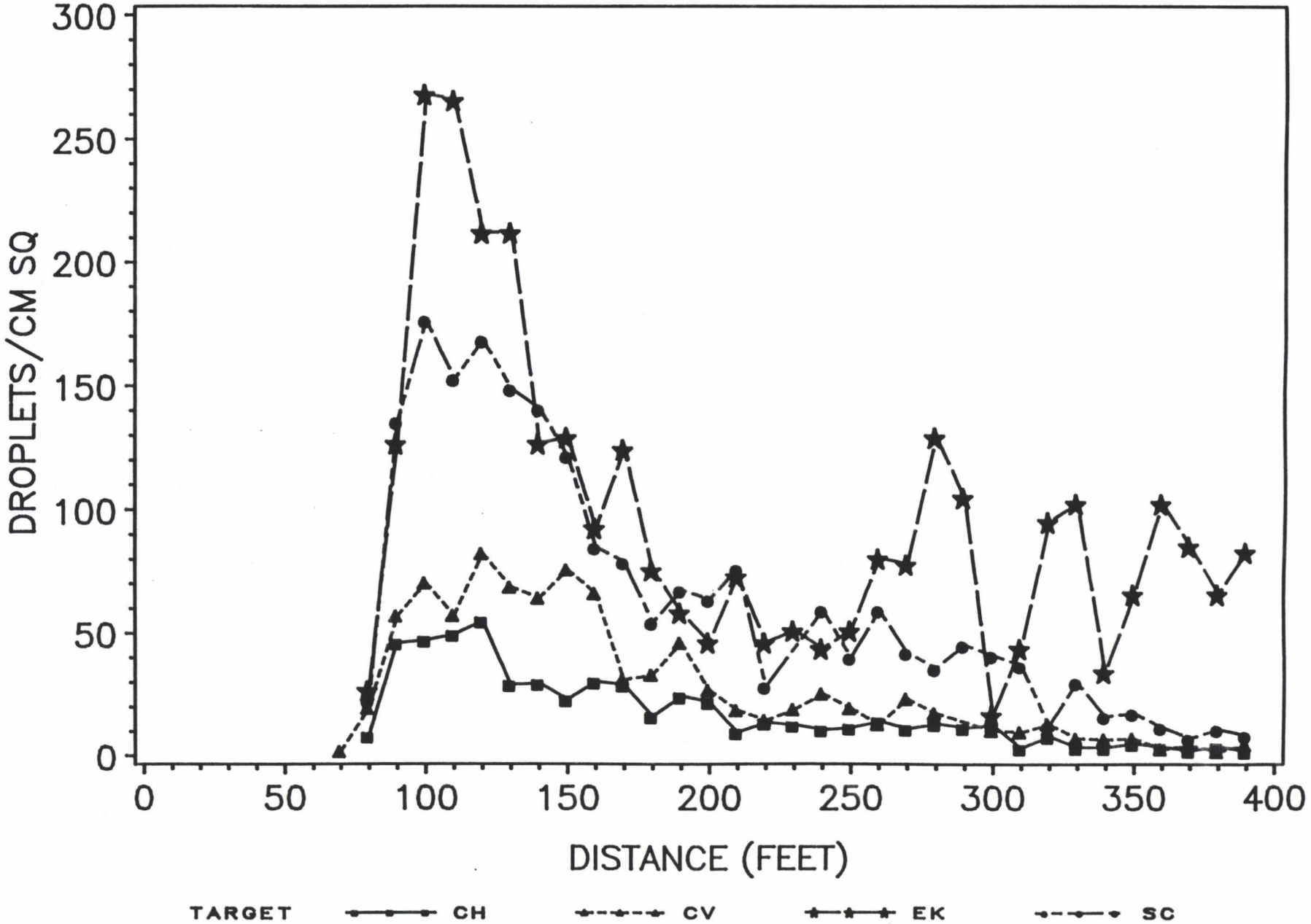

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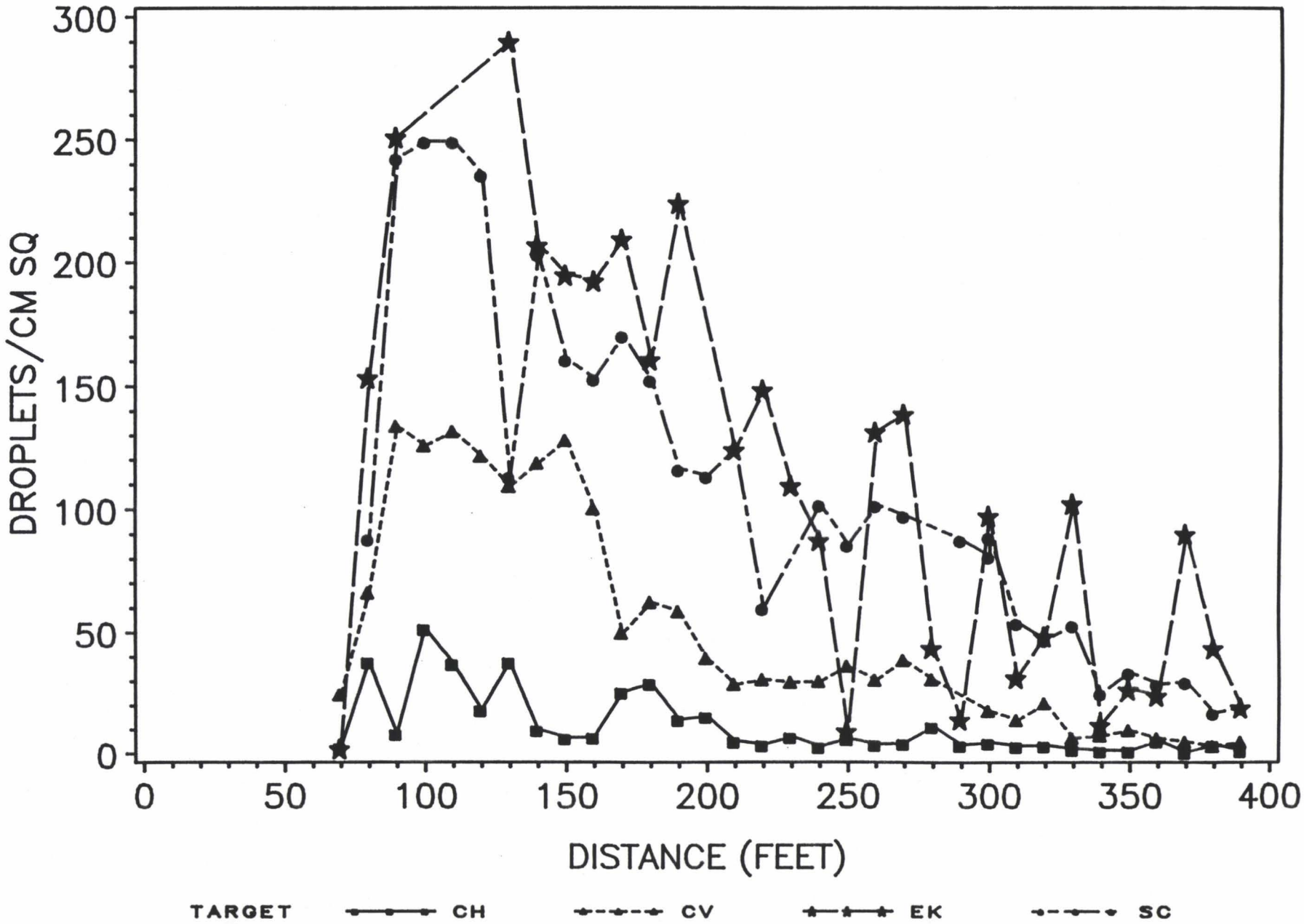

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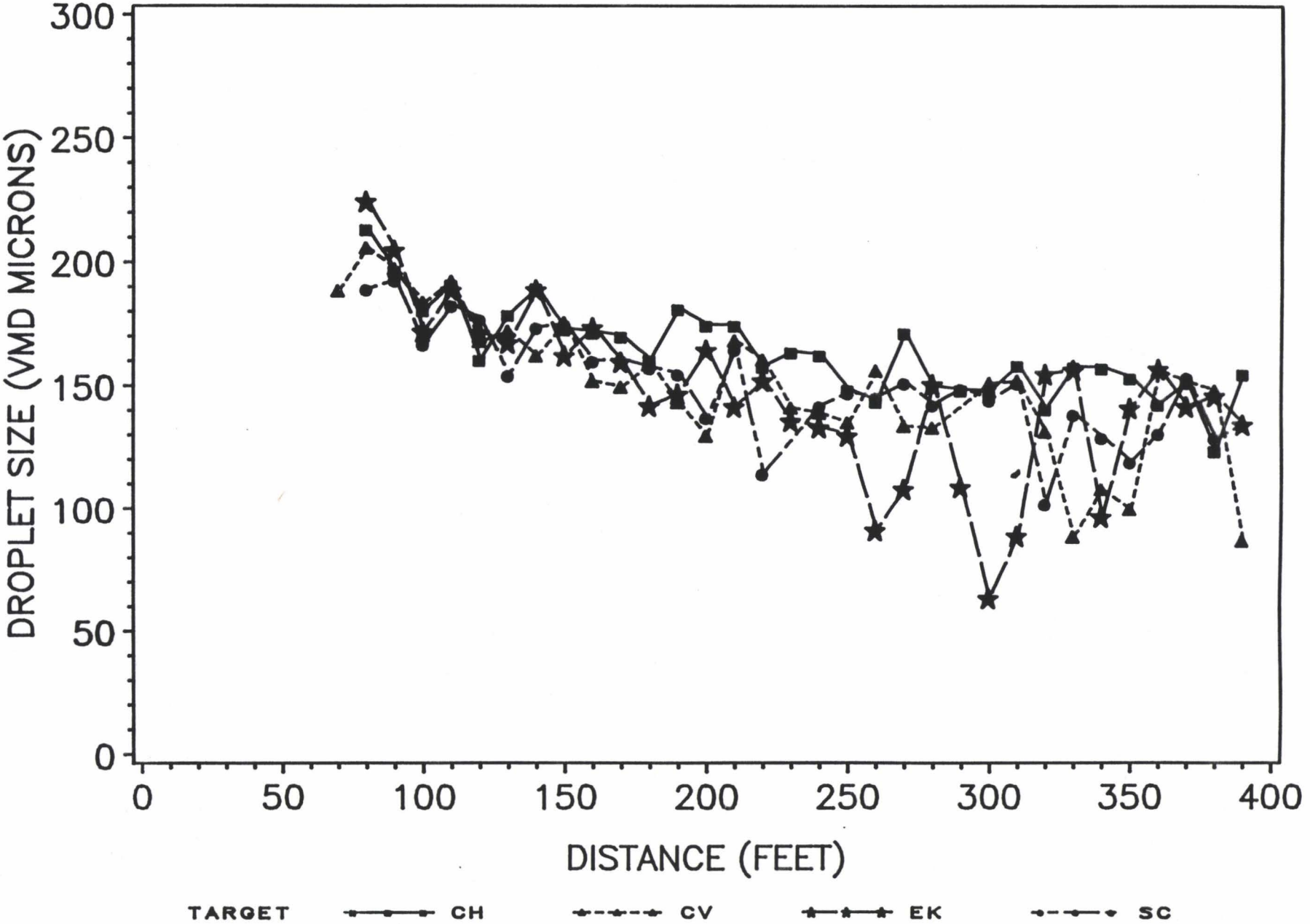

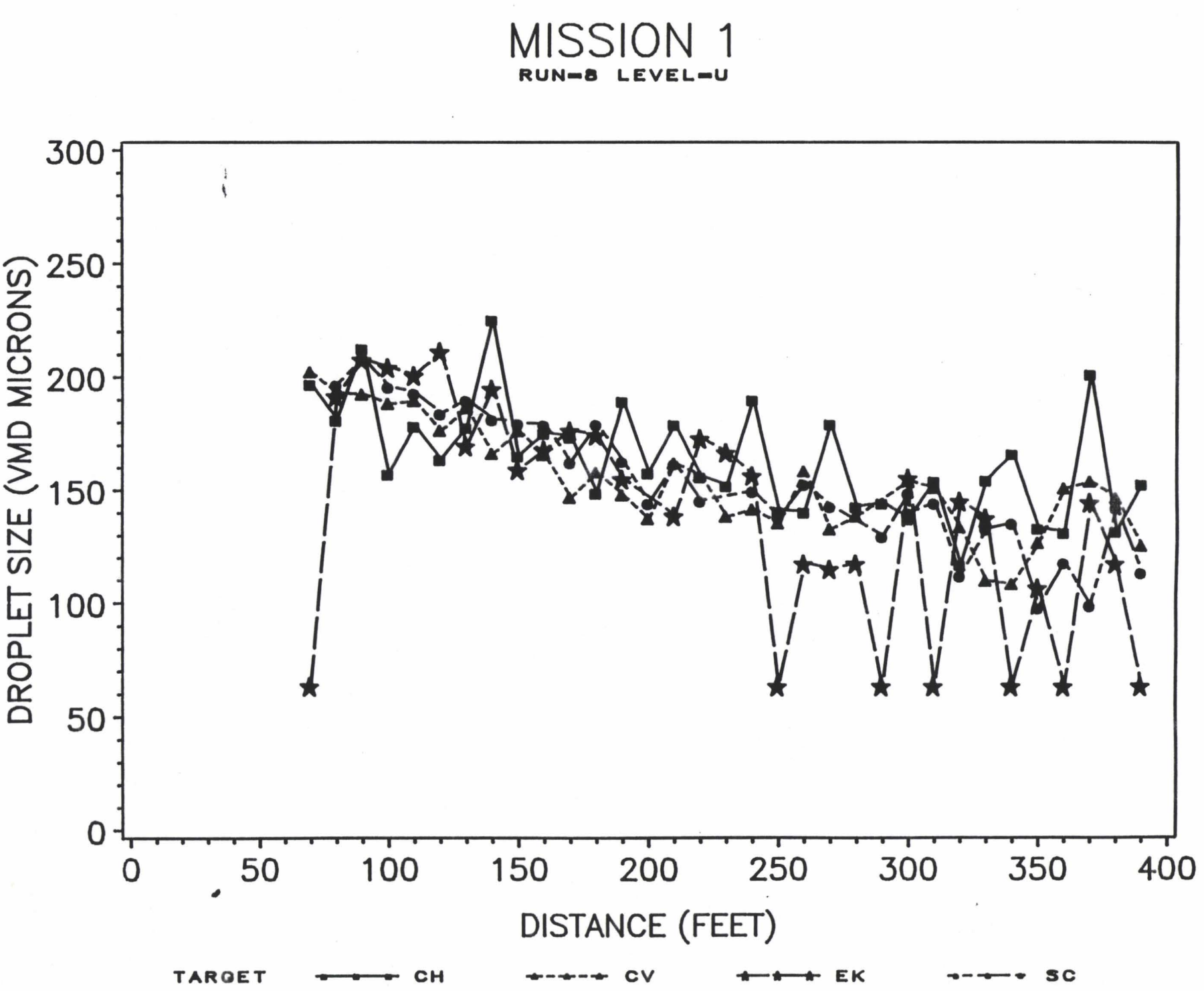
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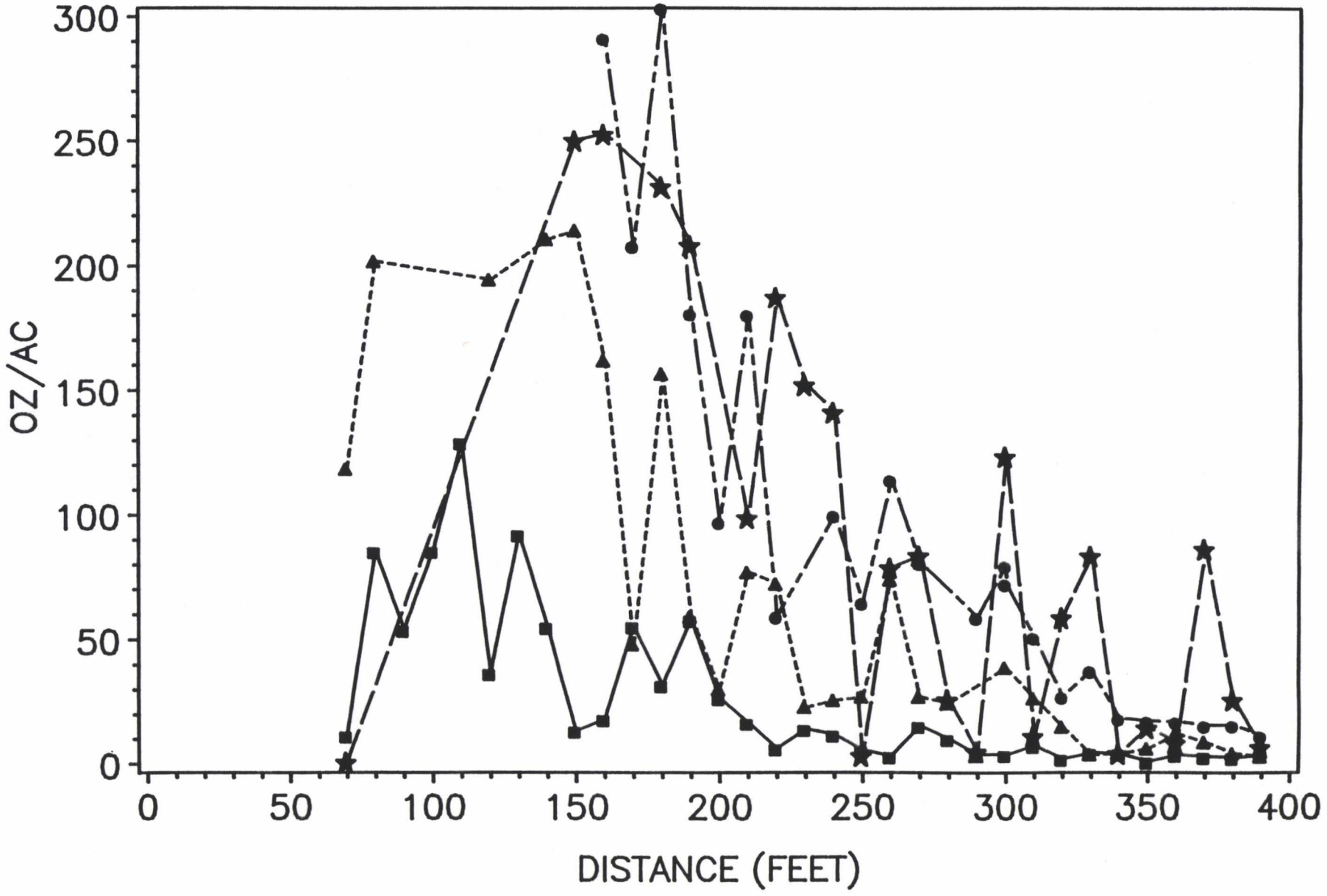
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
DISTANCE (FEET)
TARGET
CH
CV
EK
SC

MISSION 1

RUN-8 LEVEL-U



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